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METEOROLOGY FOR AIRMEN IN INDIA
PART II.

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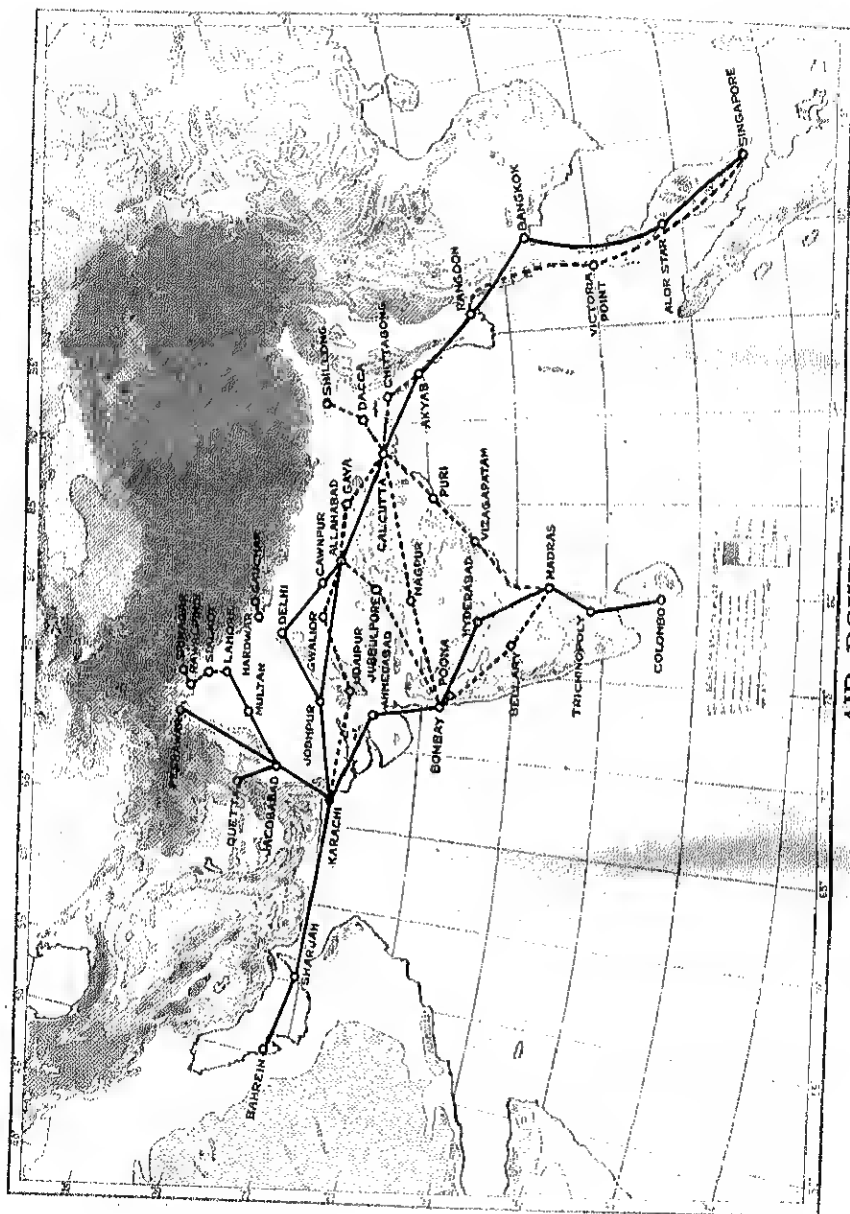
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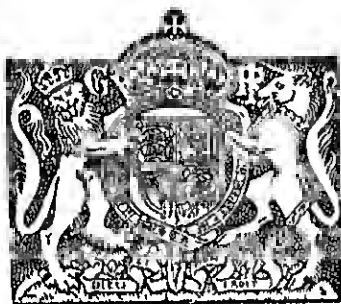
METEOROLOGY

FOR

AIRMEN IN INDIA

PART II.

CLIMATOLOGY OF AIR-ROUTES



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FOREWORD.

As indicated in the foreword to Part I, this publication is issued in two parts. Part I gives an account of the general meteorological features over the country that are of interest to airmen, and Part II the climatological notes in respect of the different air-routes.

Suggestions for increasing the usefulness of this handbook in future editions will be welcomed.

POONA ;
February 22, 1936.

C. W. B. NORMAND,
Director-General of Observatories.

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CHAPTER I.

BAHREIN/BUSHIRE—KARACHI ROUTE.

Physical features.—The air-routes from Bushire to Karachi and Bahrein to Karachi lie along the coasts of the Persian Gulf and Mekran. The low-lying coastal strips of Persia and Mekran form a narrow border to the tablelands of Iran (Persia) and Baluchistan. The tableland of Iran has, at its edges, mountains more than 3,000 ft high and the ridges along the Persian Gulf and the Mekran coast in some places rise direct from sea-level to about 3,000 ft. The distance covered by the route is approximately 2,000 miles.

Summary of important weather features.—Meteorological conditions over the region Persian Gulf to Karachi can be classified under two main types, winter and summer. In winter, December to February, a tongue of the Central Asian high pressure or anti-cyclone extends into Persia. Depressions coming from the west frequently pass through this region. The marked variation of weather depends on the movement of these western depressions and also on the position and intensity of the Central Asian anti-cyclone. In June to August, a vast low pressure area extends roughly from north-west India to Arabia; and occasionally depressions moving from the east, after passing through India or the north Arabian Sea, enter this low pressure region. The variation of weather in these months is determined by the position and intensity of the low pressure area and also to some extent by these eastern depressions.

Besides the two well-marked summer and winter periods, there are two transition periods. During the period September to November, while the summer conditions change to winter type, and during March to April, when winter conditions change to summer type, usually only localised disturbed weather conditions are met with. The conditions described above do not influence the weather over the whole route in the same way. The route may, therefore, be divided into two sections: the Persian Gulf including the Gulf of Oman, and the Mekran coast from Gwader to Karachi. Over the first section winter is the period of most disturbed weather, whereas over the second section summer is characterised by more disturbed weather than winter. The neighbourhood of Gwader may be described as the partition area.

Besides these, the varying direction of the coast line and orographic features introduce local variation in the direction and force of winds, state of sea, vertical convectional phenomena including thunderstorms and bumpiness, and incidence of fog.

Summer.—May and June are the hottest months along Mekran, but even in these months, the mean maximum temperature at coastal stations does not, generally, rise above 98°F. The south-westerly winds of the monsoon season do not affect the area west of Mekran and the temperature over the

Persian Gulf is, therefore, generally higher than that over Mekran during the hot season. This is clearly shown by the following table:—

Persian Gulf.			Mekran.		
Station.	Mean maximum temperature (°F.).		Station.	Mean maximum temperature (°F.).	
	July.	August.		July.	August.
Bushire . . .	95	97	Gwador . . .	91	87
Bahrein . . .	97	98	Pasni . . .	92	89
Lingeh . . .	90	98	Ormara . . .	91	87

The highest temperatures recorded during the hot season are 115°F. at Bushire in August, 112°F. at Charbar in July, 109°F. at Bahrein in May, 113°F. at Jask in June and 115°F. at Pasni in June.

Winter.—January is the coolest month. The mean minimum temperature does not fall below 50°F. anywhere along the route. In January, Bushire has the lowest mean minimum temperature of 51°F; elsewhere the mean minimum temperature ranges between 52° and 56°F. The lowest temperatures yet recorded are: Bushire 32°F., Bahrein 41°F. and Jask 42°F. in January; and Pasni 31°F. in February. These low temperatures are usually recorded during the passage of cold waves in the wake of the western depressions moving eastwards through this region in winter.

The mean diurnal range of temperature at stations near the coast is between 10° and 15°F. during the period June to August and 14° to 20°F. during the winter months. While these comparatively small diurnal ranges are characteristic of coastal regions, at places even a few miles inland the diurnal range is much larger.

There is very little information available regarding temperature lapse-rate in the upper air. Recent records of upper air temperatures indicate the existence of a marked temperature inversion layer during the monsoon months at a variable height ranging from 0.3 km. to 1.2 km.; the maximum values occur in July and August. This inversion layer is quite distinct from the more pronounced inversion effects near the ground during night and early morning of winter months.

Surface winds.—In January and February during spells of undisturbed weather the surface wind is generally calm or light early in the mornings and late in the evenings. Well-marked land and sea-breeze effects are, however, common during these months. During disturbed weather, which occurs during the passage of western depressions, moderate or strong easterly to southerly winds alternate with westerly to northerly winds. In March the predominating winds are light to moderate and come from north to north-west over the Gulf and west or south-west over Mekran.

By April the land and sea-breezes practically disappear over Mekran, but they persist over the Gulf up to May. Over Mekran the seasonal south-westerly to westerly winds which form part of the air circulation around north-west India begin to set in. Elsewhere conditions remain as in March.

In May the surface winds are moderate to strong, westerly to south-westerly over east Mekran, and south-westerly over west Mekran and Oman. Over the Gulf winds are mostly light north-westerly to north-easterly on the Arabian side and north-westerly to south-westerly on the Persian side.

In June and July the winds are slightly weaker than in May, being westerly to south-westerly over east Mekran and southerly to easterly over west Mekran and north-westerly to northerly over the western half of the Persian Gulf.

In August the winds become further weak and in September still weaker, but the directions are similar to those in June and July except that over the eastern half of the Gulf the more frequent wind directions are easterly to north-easterly.

By October the winds become light and land and sea-breezes become well-marked over the Gulf. The winds continue calm or light in November, and definite land and sea-breeze effects become pronounced everywhere. In December the surface winds are north-easterly over Mekran and Oman and north-westerly over the Gulf, with well marked land and sea breezes.

Local winds.—Besides the land and sea-breezes already referred to, there are other local winds called Shamal, Kaus, Suhail and Nashi.

The name *Shamal* is given to north-westerly winds over the Persian Gulf and Mekran. These winds are sometimes associated with depressions. During winter the Shamal comes as north-westerly squalls with reversal of wind directions and bumps on thunderstorms and rain which pass off rapidly. On an average a well-marked squally Shamal traverses the Persian Gulf in about 24 to 48 hours, and, if it continues to remain active, takes another 24 to 36 hours to reach Karachi. The second type of Shamal, lasting for a longer period, sometimes up to a week, occurs during the summer months due to the intensification of the seasonal low pressure over the region extending from the Persian Gulf to north-west India. These Shamals occasionally rise to gale force gradually, and fall off gradually with a return of the seasonal low pressure to the normal. The winds on such occasions carry sand and dust but are scarcely ever associated with thunderstorms or sudden squalls. The third type of Shamal blowing over the Gulf for nine months of the year and the so-called "40 days' Shamals" are nothing but seasonal winds over the Gulf.

The name *Kaus* is a local name given to south-easterly or easterly winds. The Kaus heralds the approach of a winter depression. Wet and cloudy weather during Kaus may last over a prolonged period and it is generally followed by squally Shamals. Other local winds are *Suhail* which is a south-westerly breeze and *Nashi* which is a north-easterly breeze associated with the intensification of anti-cyclonic wind circulation over lower Persia.

Upper winds.—During the winter months, at 3 km and above, the winds are mainly westerly to north-westerly over the whole route. At lower levels the predominating winds are northerly to north-westerly over the Gulf and north-westerly to westerly over Mekran. On about 20 per cent of the occasions southerly to easterly winds however occur over the Gulf in front of western depressions.

In April and May, the winds are generally north to north-westerly at lower levels. At higher levels the direction remains north to north-westerly over the Gulf, but is westerly to north-westerly over Mekran. On the Arabian side of the Gulf southerly to south-westerly winds are not infrequent in April.

During the months, June to August, the winds over the western half of the route are often strong northerly to north-westerly, whereas over the Mekran coast they are generally light and variable. At 2 and 3 km. the winds are north-westerly to north-easterly along the whole route.

In September the western side of the Gulf shows northerly to westerly winds, but in the eastern section and over Mekran, the winds, though westerly to north-westerly at lower levels change to northerly to north-easterly at higher levels. In October, the upper winds are variable and are light to moderate. Over the Persian Gulf northerly to north-westerly winds predominate. North-easterly winds are common above 2 km. between Gwador and Karachi. In November, the upper winds are very variable and in December winds above 3 km. are generally westerly to north-westerly, but at lower heights easterly and southerly components are generally frequent over the whole route. On any particular day the winds may be in opposite directions over different sections of the route, and the place of reversal of wind in such cases is often the site of a squall of the cold-front type. The north-westerly squalls which follow south-easterly winds may be severe. Those squalls are generally short-lived, but sometimes have velocities exceeding 60 km. an hour with considerable vertical convection.

Thunderstorms.—Thunderstorms occur once or twice along the route in November and December, but are more or less confined to the Persian Gulf and the entrance to the Gulf in January, February and March. In February two to three thunderstorms may occur in the Gulf. In June, July and August one or two thunderstorms associated with eastern depressions may occur in the neighbourhood of Karachi.

Cyclones.—As many as 17 Arabian Sea storms are known to have affected the section between Karachi and the Gulf of Oman or the entrance to the Persian Gulf during the last 80 years, mostly during the months of April to June. On an average the number of western depressions in winter affecting the route is 6 in January, 8 in February, 6 in March, 5 in November and 6 in December. As the winter advances, the track of these depressions becomes more and more southerly but by April they begin to recede to more northerly latitudes. The eastern depressions originating over the Bay of Bengal occasionally travel westwards as far as Karachi and its neighbourhood during the period July to September but seldom extend west of Pasni.

Cloud.—The cloudiest period over the Gulf is the winter and over Mekran the summer. In winter the average amount of cloud varies from 5* over the Gulf to 2 or 3 over the Mekran and Sind coasts; the percentage of low cloud is about 50 per cent. of the total amount over the Gulf, but eastwards medium or high clouds are more frequent. During summer, skies are practically cloudless over the Gulf but over the Sind coast the average cloud amount is 7 near Karachi and decreases gradually as one goes westwards through Mekran; the clouds are mostly low. The period of minimum cloudiness over the Gulf is June to August; and over Mekran October to November, and March to April.

Rainfall.—The precipitation over the area is usually associated with western depressions in winter and with eastern depressions in summer. The western depressions originate to the west of the area and move eastwards; the eastern depressions originate mostly in the Bay of Bengal and travel into or towards north-west India. Rain over the Gulf is caused by western

* Whole sky cloudy = 10.

depressions, while rain over Lower Sind and east Makran is due mainly to eastern depressions.

The average rainfall of January varies from 2.73 ins at Bushire to 0.52 ins, at Karachi. The number of rainy days varies from 5 at the head of the Gulf to 2 over the eastern section of the Gulf. The number of rainy days gradually decreases from 2 to 1 as one proceeds eastwards from the Gulf of Oman towards Karachi. The average total rainfall in February varies from 1.94 ins at Bushire to 0.39 ins at Karachi. In March, rainfall is generally of the thunderstorm type and occurs on 1 to 3 days in some years. The average total amount is 0.97 ins at Bushire decreasing eastwards to 0.33 ins at Karachi. On a few occasions thunder and lightning are observed without rainfall. In April, once in three years, rainfall associated with thunderstorms occurs and the average rainfall varies from 0.51 ins at Bushire to 0.17 ins, at Karachi. In May, June, July, August and September, the Persian Gulf practically remains dry, whereas over the rest of the region rainfall associated with the eastern depressions occurs. June and July are the wettest months. The average rainfall at Karachi during July is 2.04 ins, with the number of rainy days as large as 11 in some years. The rainfall rapidly falls off westwards, and at Muscat it is only 0.02 ins. In August rainfall occurs on about 2 days at Karachi with an average total of 1.67 ins. It decreases rapidly westwards and becomes negligible west of Gwadar. Over the Gulf of Oman, including Jask and Muscat, rainfall may be expected once in five years in this month. In September, two eastern depressions on the average cause rain in the neighbourhood of Karachi, the average number of rainy days being one. Rainfall seldom extends westwards up to Pasni. Rainfall is very variable in lower Sind, and in some years rainfall has occurred at Karachi about equal to, or more than, its annual total in a couple of days.

Visibility.—Visibility is generally good during the period January to April except during showers and duststorms or occasional fog. During the months May, June, July and August, visibility slowly deteriorates, July and August being the worst months, when the visibility is more often likely to be fair (4-8) than good (7-9). By September, the visibility conditions generally improve and in October, November and December the visibility is good except locally during disturbed weather, when duststorms and dust haze are possible.

Fog is likely on about 2 days in the Persian Gulf and 1 or 2 days along the Makran coast in January. In February or March it is likely on an average on 1 day over the Gulf and on 2 or 3 days over the section Jask—Karachi. Morning fog is likely along Makran coast on 2 or 3 days in September, 4 or 5 days in October and 1 or 2 days in November. In December fog occurs on 2 or 3 days over the western section of the Gulf.

Duststorms occur about once in each month over the Gulf, and twice over the rest of the section during the period January to April. Duststorms associated with high winds and poor visibility occur most frequently during the months May, June and July; 3 to 4 duststorms are reported from Makran, in May and about the same number over the whole route in June. In winter, during the passage of strong western disturbances, in the absence of recent rainfall, severe duststorms or sand storms may occur in the cold front region. These sometimes carry dust as far east as Karachi. Dust-haze with poor visibility is reported on 4 to 8 days from the Karachi—Jask section in May, but in June and July it is more frequently reported from the Gulf stations.

CHAPTER 2.

KARACHI—CALCUTTA ROUTE.

The following are the principal air routes between Karachi and Calcutta :—

- (a) Karachi—Jodhpur—Allahabad.
- (b) Karachi—Udaipur—Gwalior—Allahabad.
- (c) Karachi—Delhi—Cawnpore—Allahabad.
- (d) Allahabad—Gaya—Calcutta.

The first one is the trunk route. It passes over Jodhpur, over the Sind and Rajputana deserts and then over the Gangetic plain of the United Provinces to Allahabad. The second one is an alternative route between Karachi and Allahabad, and passes over lower Sind, Rajputana and the Gangetic plain of the United Provinces. The third route is adopted if the flight is made from Karachi *via* Delhi or independently.

Physical features.—All these routes lie mainly over the great plain of northern India which is bounded on the north by the Himalayan mountain wall and forms a great curve from the Arabian Sea to the Bay of Bengal. It is more than 2,000 miles from end to end, and is usually from 150 to 200 miles broad. This great plain is formed by the basins of three rivers and their tributaries. In the west and draining into the Arabian Sea is the river Indus. Further east is the river Ganges, which flows south-eastwards into the Bay of Bengal. The city of Delhi stands nearly on the watershed between these two river basins. Before the Ganges reaches the sea it is joined by the third of the mighty rivers, the Brahmaputra. Throughout the whole of the Indus and Ganges plain there is scarcely a hill to be seen. Nearly 1,000 miles from the mouth, the surface of the river Ganges is only 500 feet above sea-level. Bounding this great plain is the Aravalli range in the south-west and the Vindhya range in the south, seldom rising to a height of more than 2 km.

Summary of important weather features.—The first half of the Karachi to Allahabad route passes over the north-west dry area. This is on the whole the driest region in India and is subject to extremes of heat and cold. Here the monsoon season is very short, lasting only from about the end of June to the middle of September; in Rajputana it is somewhat more prolonged but in Sind rainfall is scanty. Occasional rain is received in the first three months and the last month of the year during the passage of western disturbances, but its average amount is less than twenty per cent. of that recorded during the prevalence of the summer monsoon. The total rainfall of the year is about 6½ ins. in lower Sind, 21 ins. in Rajputana and 27 ins. near Delhi; but even in a place like Karachi, rainfall almost equal to its annual total has been known to fall in the course of 24 hours during the westward movement of storms from the head of the Bay of Bengal. The highest temperatures in India are recorded in the north-west dry area between May and September. June is the hottest month, with a mean temperature of 92°F. and an average of 104°F. in the afternoon; the absolute highest on record varies between 112° and 127°F. in the different districts. The northern part of the route lies in a region which, from December to January, is the coolest in the plains of India. January has a mean temperature of only 59°F. and a mean minimum of 47°F. and, except in the maritime tract represented

by lower Sind, temperatures of 25° to 31°F. in the early morning are not unknown. The diurnal range of temperature is very large and amounts often to over 30°F.

The second half of the Karachi to Allahabad route lies over the Gangetic plain. The only period of the year characterised by really wet weather is from about the middle of June to the middle of October, the period of the south-west monsoon. Occasionally rain is received during the winter months from the cold weather storms (western disturbances), but it is generally light. From April until the beginning of the monsoon the tract is swept by hot and excessively dry westerly winds, and temperatures ranging between 110° to 120°F are occasionally recorded. The withdrawal of the monsoon is succeeded by the prevalence for eight or ten weeks of pleasant fine weather with a decreasing temperature. During the first three months of the year large fluctuations of temperature occasionally occur in connexion with the passage of western disturbances, and in the United Provinces the thermometer at night may then sink to 29° or 30°F. The diurnal range of temperature exceeds 20°F during the dry season and is about half that amount during the rains.

Over the portion Allahabad to Calcutta the period November to March is practically dry, except for occasional light rain. Thunderstorms (and occasionally Nor'westers in Bengal) occur in April and May and the showers associated with these merge in the monsoon rainfall in the first half of June. The rainy season lasts up to about the middle or end of October. The annual rainfall varies between 40 and 70 inches over a large part of the tract. Except in the east United Provinces and Bihar, the air is very damp during the greater part of the year, and from May to September dense cloud covers the sky. Temperature is fairly high, the average afternoon temperature of the hottest months is 90°F and upwards. In the maritime tracts of Bengal the thermometer never sinks below 39°F.

(a) KARACHI—JODHPUR—ALLAHABAD.

Air temperature.—December and January are the coolest months along this route. On the average the minimum temperature does not fall below 50°F along the route from Karachi to Hyderabad nor below 45°F over the rest of the section. Occasionally however much lower temperatures than these do occur, some of the lowest temperatures recorded being 30°F. at Karachi in December, 31°F. at Hyderabad and 28°F. at Jodhpur in January; and 31°F. at Allahabad in February.

May and June are the hottest months. On the average maximum temperature does not go above 110°F. in any part of the route. Occasional days are however much hotter, some of the highest recorded temperatures being: 118°F. at Karachi in May, 122°F. at Hyderabad, 121°F. at Jodhpur and 120°F. at Allahabad, in June. The average maximum temperature falls with the onset of the monsoon, when it is of the order of 84°F. along the route.

The diurnal range of temperature is lowest during the rainy season when it is of the order of 10° to 20°F. After the rains the range increases and reaches its highest value of 25° to 35°F. in November. During the rest of the year it is of the order of 20° to 30°F. except in the neighbourhood of Karachi in the hot weather, when the effect of the sea-breeze in lowering the range becomes well marked.

Surface winds.—In the cool season from November to February the air movement at the ground level is from the north, with easterly components near Jodhpur and westerly components near Allahabad,

In March, which is a period of transition from the winter to hot weather, the ground winds are generally from west, with a southerly component near Jodhpur and a northerly component from Jhansi to Allahabad. The wind directions along the route continue to be practically the same as above during the months April to June. The frequency of westerly to south-westerly winds, however, increases over the section Karachi to Jhansi with the onset of the monsoon in July. Near Allahabad ground winds are generally from west or west-north-west when the monsoon is weak, and from east or south-east when the monsoon is active. With the westward movement of monsoon depressions through the centre of the country, easterly winds often penetrate up to Jodhpur and on rare occasions even further west.

In October, which marks the transition from monsoon to winter, the direction is south-westerly over the Karachi—Jodhpur section and thence changes through west to north-west over the Jhansi—Allahabad section.

Upper winds.—In the cool season, the upper winds are generally from west to north-west and have a velocity of less than 25 km./hr. below 1 km.; the velocity increases with height above that level. There is a fair percentage of winds from north-east or east at Karachi in November, December and January; near Jodhpur southerly components are fairly frequent up to 1 km. in November and December and an easterly component from January to March.

During hot weather, the upper winds are of the same character as in the cool season. At Karachi in lower levels westerly winds become predominant in May and still more so in June. As in the last season, near Jodhpur southerly winds in April and easterly in June are also prevalent on some occasions. In May, June and July, the pressure gradient over the Jodhpur—Jhansi—Allahabad section may occasionally become very steep and result in strong, 50 to 60 km./hr., westerly or west-north-westerly winds in the free air at all the ordinary flying levels.

With the onset of the monsoon there is a general strengthening of the free air winds especially in the first 1 km. The winds continue during July to September to be from west or north-west, except when replaced by easterly currents associated with depressions from the Bay of Bengal.

Thunderstorms.—The period of thunderstorm activity extends from May to September, the highest monthly frequency of about 2 or 3 occurring in July near Karachi, and of about 6 or 7 in July and August over the Jodhpur—Allahabad section. The annual frequency of thunderstorms ranges from 10 near Karachi to 30 near Allahabad. The thunderstorms during the hot weather (April—June) do not usually cause appreciable rain but are frequently associated with squalls of dust.

Cyclonic storms and depressions.—During the period November to May, a series of disturbances, about 4 to 6 each month, enters north-west India from the west. These western disturbances are responsible for the cloudiness and light rain along the Karachi—Allahabad section in winter and for most of the dust-storms in the hot weather. In the rainy season, depressions originating at the head of the Bay of Bengal travel through the centre of India in a westerly or north-westerly direction and occasionally cause low "overcasts" and locally heavy rain along and near this aerial route. Cyclonic storms which originate in the Arabian Sea in May, June and November may, on rare occasions, also affect weather over this section.

Cloud.—July and August are the most cloudy months in the year cloudiness being greater over the Jodhpur—Allahabad section than over the

Karachi—Jodhpur section. With the withdrawal of the monsoon towards the end of September there is a clearing of the skies, October and November being the months with minimum cloudiness along this route. In the cold weather (December—February) there is again an increase in cloudiness due to the passage of western disturbances over northern India. The amount of cloud during these months is, however, much less than in the monsoon months. The hot weather, April and May, is again a period of little cloud in this section.

Rainfall.—The rainfall over the route is mainly due to two distinct agencies—the western disturbances and the monsoon depressions. The amount of precipitation produced by the western disturbances is on the average much less than that due to the monsoon depressions, which, however, affect the Allahabad—Jodhpur section more than the rest of this route. The distribution of rain is characterised by a progressive decrease from Allahabad with an annual average of 39 ins. and with 49 rainy days, to Karachi with an average of 8 ins. with 9 rainy days only.

Visibility.—Duststorms or dust raising winds and dusthaze are fairly frequent in the hot season. Visibility is sometimes reduced to an extraordinarily poor range during the passage of a duststorm. Morning fogs are not unusual in winter and may occasionally be quite thick during the passage of western disturbances. During the monsoon, drizzling and heavy rain are the chief factors which may affect visibility adversely.

(b) KARACHI—UDAIPUR—GWALIOR—ALLAHABAD

The conditions over this route do not differ materially from those over the trunk route. Owing to orography, however, there is generally more rain, as well as cloud, in and around the hills of Mount Abu than in other parts of the route; also low clouds over the hills may affect visibility adversely.

(c) DELHI—CANNPORE—ALLAHABAD

The conditions over this portion of the route are more or less the same as over the portion Jhansi—Allahabad of the trunk route.

Air temperature.—The monthly mean minimum temperature does not fall below 45°F. at any place over the section. Some of the lowest temperatures recorded on individual nights are 32°F. at Delhi and 34°F. at Agra in January and February, and 33°F. at Cawnpore in February.

The monthly mean maximum temperature does not go above 107°F. in the section. Some of the highest recorded temperatures are 118°F. at Delhi, 120°F. at Agra, 117°F. at Cawnpore and 120°F. at Allahabad, all in June. The mean maximum temperature decreases with the onset of the monsoon to the order of 92°F.

The diurnal range is of the order of 10° to 15°F. during the monsoon increases to 25° to 30°F. in November, falls to 25°F. in December and January, and reaches the highest value of about 30°F. in March and April.

Surface winds.—Winds at the ground level along the route Delhi to Allahabad are mostly between north-west and south-west with a fairly large percentage of calms in the morning during the cold season, October to March.

During the hot season, April to June, the winds strengthen and the frequency of occurrence of calms also decreases, although the most frequent

directions still lie between north-west and south-west along the route, the frequency of easterly and south-easterly winds increases, especially during May and June, due to the establishment of the seasonal trough of low pressure along the Gangetic valley.

During the rainy season, July to September, the winds most frequently blow from between south-east and south-west along the Delhi--Agra section; near Allahabad the winds are generally from west or west-north-west when the monsoon is weak and from east or south-east when the monsoon is active.

Upper winds.—As in the Jhansi--Allahabad route the upper air movement in the cool season is mostly from west to north-west and its average strength is generally less than 25 km./hr. below 1 km.; the force increases with height above that level.

In May, June and July, the pressure gradient occasionally becomes very steep and causes strong (50 to 65 km./hr.) westerly or west-north-westerly winds in the free air at the ordinary flying levels.

During the monsoon, July to September, the winds blow from west or north-west except when replaced by easterly currents under the influence of depressions from the Bay of Bengal. The velocities are generally 25 to 50 km./hr. The easterlies increase in frequency as one goes from Delhi to Allahabad.

Thunderstorms.—The period of thunderstorm activity extends from May to September, the highest monthly frequency being about 4 or 5 occurring in July near Delhi, and about 7 or 8 in July and August near Allahabad. The annual frequency of thunderstorms ranges from 25 near Delhi to 30 near Allahabad. The thunderstorms during the hot weather (April--June) do not usually cause appreciable rain but are frequently associated with squalls raising huge quantities of dust.

Cyclonic storms and depressions.—During the period November to May, a series of disturbances, about 4 to 6 each month, enters north-west India from the west. These western disturbances cause cloudiness and rain along the Delhi--Allahabad section in winter, and most of the duststorms in hot weather. In the rainy season, depressions originating at the head of the Bay of Bengal travel along the Gangetic plain in a westerly or north-westerly direction and occasionally cause overcast skies and locally heavy rain along and near this aerial route.

Cloud.—July and August are the most cloudy months in the year, cloudiness being greater over the Cawnpore--Allahabad section than over the Delhi--Agra section. With the withdrawal of the monsoon towards the end of September there is a clearing of the skies, October and November being the months with minimum cloudiness along this route. In the cold weather (December--February) there is again an increase in cloudiness due to the passage of western disturbances over northern India. The cloud in these months due to these disturbances is, however, much less than that in the monsoon months. The hot season (April and May) is again a period of little cloud in this section.

Rainfall.—The rainfall over the route is mainly due to two distinct agencies—the western disturbances and the monsoon depressions. The amount of precipitation produced by the western disturbances is on the average much less than that produced by the monsoon depressions. Accordingly the distribution of rain shows a progressive decrease from Allahabad with an annual fall of 39 inches, to Delhi where only 27 inches of rain fall in the year.

Visibility.—Over this route, duststorms, dust raising winds and dusthaze are fairly frequent during the hot season. Visibility is sometimes reduced to very low figures during the passage of a duststorm. Morning fogs are not unusual in winter and may occasionally be quite thick immediately after the passage of western disturbances. During the monsoon, drizzling and heavy rain are the chief factors which affect visibility adversely.

(d) ALLAHABAD—GAYA—CALCUTTA.

Air temperature.—December and January are the coldest months. In the cold season, November to February, the mean minimum temperature does not fall below 47°F along the Allahabad—Gaya section of the route and 51°F along the Gaya—Calcutta section. The lowest recorded temperatures are 34°F. at Allahabad and Benares and 40°F. at Burdwan in February; and 40°F. at Gaya in December.

April and May are the hottest months. In the hot season, March to May, the mean maximum temperature does not rise above 107°F along the Allahabad—Gaya section of the route and 102°F along the Bengal section. The highest temperatures on record are 120°F. at Allahabad in June, 117°F. at Benares in May and June, 116°F. at Gaya in June, 115°F. at Ayansol and Burdwan in May, and 108°F. at Calcutta in June.

During June and July the maximum temperature comes down considerably. The mean maximum temperature during the rainy season, June to October, lies between 89° and 102°F. in the east United Provinces and between 84° and 95°F. in Bengal.

The diurnal range of temperature along the route is of the order of 10° to 15°F. during the months July to September. With the cessation of rain, it increases rapidly from 15° to 25°F. in October, and then increases slowly from month to month until the maximum range of 20° to 30°F. is reached in March and April. After April the diurnal range again begins to fall and is of the order of 15° to 20°F. in June.

Surface winds.—Ground winds along the route are mostly between north and west during the cold season with a fairly large percentage of calms in the morning. In the east United Provinces and the adjacent districts of Bihar, the north westerly wind continues up to the end of May, after which the wind becomes variable and remains so throughout the monsoon season. After October the winds in this section again become north-westerly. In Bengal and Chota Nagpur the ground winds in the hot season have a southerly component varying between south west and south. By the end of May they change to east or south east and remain so till the end of September.

Upper winds. (i) *Cold Season.*—In the lower levels up to 1 km. the winds generally blow from directions between north and north-west with a velocity less than 25 km./hr. Higher, up to 3 km., they are generally stronger, i.e., from 25 to 50 km./hr., the most frequent direction being between north-west and west.

(ii) *Hot Season.*—In this season winds near Allahabad are generally 25 to 50 km./hr. between north-west and west at all levels up to 3 km. Winds near Calcutta are generally 25 to 50 km./hr., south-westerly up to 1 km.; between north-west and west and less than 25 km./hr. at 2 km., and 25 to 50 km./hr. and again between north-west and west at higher levels up to 3 km.

(iii) *Rainy Season*.—In this season, the winds near Allahabad are generally between west and north-west in the first kilometre, and become northerly to north-westerly at higher levels. Under the influence of depressions, easterly to north-easterly winds occur. Near Calcutta, in the months June to September, the most frequent direction is between south and south-west in the first kilometre and between south and west above; in October, the most frequent direction up to 1 km. is northerly. Throughout the season, the wind at 3 km. is variable. From June to August, the wind speeds between Allahabad and Ranchi are 25 to 50 km./hr. at all levels up to 3 km.; in September and October, they get weaker. Near Calcutta, the winds are light to moderate from June to the middle of September and generally light in the latter half of September and October.

Thunderstorms and Nor'westers.—In the east United Provinces and Bihar section thunderstorms mostly occur during the period May to September with the highest frequency, of about 6 or 7, in each of the months of June and July. In the Bengal section the period of thunderstorm activity extends from March to October with the highest frequency, of about 8 or 9, in each of the months of April, May and September. The annual frequency of thunderstorms along the route is 40 to 50 days in the year.

The remarks regarding Nor'westers given in the section for the Calcutta—Rangoon route (p. 16) apply equally well for this portion of the route also.

Cyclonic storms and depressions.—These are experienced mostly during the period May to November, but are more frequent in June to September. During a period of 32 years the numbers of storms and depressions either crossing the Calcutta—Allahabad route or passing near it are as follows:—4 in May, 12 in June, 11 in July, 9 in August, 11 in September, 7 in October and 3 in November. In May, October and November they generally originate in the central region of the Bay of Bengal and after a northerly travel recurve towards the Circars-Orissa coast; and sometimes they also move to Bengal and the Arakan coast. Some of these storms pass into the Bay of Bengal from the China Seas across Burma during the months of October and November. During the months June to September they develop over the head of the Bay and generally travel north-westwards across the Bengal and Orissa coasts.

Cloud.—The cloud amounts are greatest during the monsoon season, July and August being the cloudiest months with practically overcast skies. From September onwards the amount begins to decrease till it reaches its minimum in the months of November and December. Along the Allahabad-Gaya section of the route clouds increase slightly in January and February in association with the eastward passage of western disturbances across northern India. A secondary minimum occurs again in the months of March or April.

In the hot season the height of base of low clouds is usually above 0·5 km. In the rainy season and in winter, low overcasts with ceilings below 300 metres may sometimes occur and in exceptional cases be as low as about 75 to 175 metres. In the hilly regions of Chota Nagpur the hill tops may often be enveloped in low clouds on rainy days.

Rainfall.—The average annual rainfall varies from 39 ins. at Allahabad with 49 rainy days to 63 ins. at Calcutta with 85 rainy days. Of those about 36 ins. fall during the rainy season June to October at Allahabad on about 43

rainy days and about 51 ins. at Calcutta on about 60 rainy days. During the passage of storms and depressions from the Bay of Bengal across or along this air route and due to occasional thunderstorms very heavy rain occurs locally during the rainy season, the individual falls during 24 hours amounting sometimes to 5 or 10 inches.

Visibility.—On the Burdwan-Gaya section fog or mist is likely to be encountered on most mornings during the cold season until about 8 A. M. and occasionally later. During the rainy season visibility is considerably reduced when rain is falling and is bad whenever the intensity of rain is moderate or heavy. At other times visibility is generally fair to good.

CHAPTER 3.

CALCUTTA—SINGAPORE ROUTE

(a) CALCUTTA—AKYAB—RANGOON.

This is one of the most difficult air-routes, both on account of the physical features of the Burmese Peninsula and the severity of the weather which prevails over the route during many months of the year.

Physical features.—The Arakan Yoma which runs parallel to the coast down south to Cape Negrais is an extension of the many ranges that radiate southwards from the Eastern Himalayas along the eastern borderland of Assam forming an effective barrier between Burma and India proper. The Arakan Yoma is fairly high, some of its peaks (e.g., Mount Victoria) rising to over 10,000 feet. The coastal strip between the Arakan Yoma and the Bay of Bengal is hilly and is mostly covered with dense forests of bamboo thickets. From Naaf to Sandoway river the coastal line is broken into a number of low islands by a net-work of estuaries and creeks with wide muddy channels. From Sandoway to Cape Negrais, the foot hills of the Arakan Yoma come very close to the sea and form a rugged and rocky barrier along the seashore with occasional sandy bays at the mouths of the hill streams. The Shan plateau occupies the whole of the east of the country and extends southwards into Tonasserim. The plateau averages 3,000 ft. in height with peaks 6,000 to 7,000 ft. high. Between the Arakan Yoma and the Shan plateau is the central basin of the Irrawaddy and Sittang rivers. This is for the most part a lowland area with the Pegu Yoma, a range of low hills, running in the centre from north to south and forming the watershed between the lower courses of the Irrawaddy and Sittang. This lowland region expands at its southern extremity into the deltaic area of the Irrawaddy and the Sittang; in this region flat sandy beaches run almost due east as far as the mouth of the Salween river near Moulmein.

Summary of important weather features.—Except for occasional light rain, the period December to March is practically dry. Thunderstorms occur in April and May; in the first half of June they become merged in the monsoon rainfall. The rainy season lasts up to about the middle or end of October. The annual rainfall varies between 50 and 100 ins. over a large part of the tract, and on the Burmese and east Bengal coasts it considerably exceeds even 100 inches. In the centre of Burma there is a zone where only 20 to 30 ins. fall during the whole year. Except in the dry zone of Burma, the air is very damp during the greater part of the year, and from May to September dense cloud covers the sky. Temperature is moderately high, the mean maximum for the year ranging from about 80°F. in Assam to over 90°F. in Central Burma and the mean minimum between 60° and 75°F. The mean annual diurnal range generally is only about half of that in the north-west dry area.

In the coastal districts the air is very damp almost throughout the year relative humidity being above 90 per cent. in the rainy season. It is only in central Burma that the humidity falls below 60 per cent. in the dry months of March and April.

Air temperature.—January is the coolest month. The temperatures along the coast are somewhat lower than in the interior owing to proximity to the sea. The mean minimum temperature does not fall below 53°F. along the Bengal coast and 59°F. along the Burma section of the route. In individual

years temperatures have fallen as low as 10°F . in January and February in south east Bengal, and 53°F . at Meigu, in Tonassero, in January

April and May are the hottest months in Bengal, and March and April in Burma. The mean maximum temperature does not rise above 95°F . in Bengal and 98°F . in Burma. The highest individual temperatures on record are 108°F . at Calcutta in June, 109°F . in April in Jessore, 111°F . at Krishnagar in April and May, 105°F . at Victoria Point in May, 105°F . at Bassora in April, and 106°F . at Rangoon in April

During the rainy season there is only a slight fall in the maximum temperature. The mean maximum temperatures do not fall below 85°F . in Bengal and 83°F . in Burma and are seldom above 91°F . in Bengal and 89°F . in Burma

The diurnal range of temperature is of the order of 10°F . along the whole route during the monsoon season. The diurnal range increases during the months of October and November attaining a maximum value of the order of 20° to 25°F . during the winter months December-March, after which the range rapidly diminishes again

Surface winds.—The winds are mostly between north and east during the cool season with a fairly large percentage of calms in the mornings during the months January and February. By the end of April in the Bengal section of the route, wind direction begins to have a definite southerly component varying between south east and south until the end of the monsoon season when the wind direction begins to have a predominant easterly component. The southerly components set in along the Arakan coast a little later. Beginning from June until the end of September the winds generally blow from some direction between south-west and south east. In the Rangoon to Victoria Point section the southerly to south-westerly monsoon winds begin to set in earlier in May and last until September

Upper winds (i) *Cool season*—In the lower levels up to 2 km. north-easterly winds are frequent during November to February on the Bengal coast. In Burma, the winds vary in different parts of the coast, being north easterly to south-easterly at Akyab in November and December and northerly in January and February. At Rangoon north-easterly and easterly winds are frequent in November and December and northerly in January and February. Above 2 km. westerly to north-westerly winds prevail in Bengal and south-westerly to north-westerly winds prevail in the Arakan coast. Near Rangoon easterly to south easterly winds continue in November, but by December the wind direction changes to a north easterly and later to a westerly direction in January and February

(ii) *Hot season*—The winds blow with greater velocity (i.e., between 25 to 50 km/hr) during most of this period. At lower levels they are mainly southerly to south-westerly along the Bengal coast, with a few occasions of winds with easterly components. At Chittagong the winds are north-easterly to south-easterly in March, and southerly to south-westerly in April and May, at Akyab northerly to north-westerly winds are frequent in March, and north-westerly to westerly winds are predominant in April and May with about 20 per cent occasions of south-westerly winds. South easterly to south-westerly winds prevail at Rangoon in March but these change to westerly to south-westerly winds during April and May. At higher levels above 3 km. westerly winds prevail generally along the Bengal and Arakan coasts; easterly winds are experienced along the Arakan coast on about 30 per cent occasions, at Rangoon the winds at these levels are variable

(iii) *Rainy season*.—The rainy season may be said to be characterised by fairly strong winds in the upper regions along the Burma section of the route, the velocity during most of the period being 25 to 50 km./hr. At all levels up to 3 km. south-westerly to southerly winds are frequent at Calcutta, and south-easterly to southerly winds at Dacca and Chittagong. The winds are southerly to south-westerly at Akyab and south-westerly to westerly at Rangoon. Above 3 km. the winds are variable along the Bengal coast, south-easterly to south-westerly at Akyab and south-westerly to westerly at Rangoon.

By October the south-west monsoon has retreated and the higher velocity characteristic of the winds of the preceding months disappears; the winds in the lower levels are northerly to north-easterly at Calcutta, somewhat variable at Dacca, between south-easterly and south-westerly along the Arakan coast, and easterly to south-easterly at Rangoon. In the higher levels, they are north-westerly to south-westerly at Calcutta, south-westerly to westerly at Dacca, south-easterly to south-westerly at Chittagong and Akyab, and easterly to south-easterly at Rangoon.

Thunderstorms and Nor'westers.—Thunderstorms mostly occur during the period April to October, but April, May and September are the months when they are most frequent in Bengal, about 6 occurring in each month; and May and October are the months with maximum frequency of thunderstorms in Arakan and Pegu, about 10 occurring in each month.

Nor'westers are a type of thunderstorms characteristic of Bengal and Assam, usually very sharply restricted in area and frequently very destructive. They usually occur late in the afternoon, sweeping the country in more or less straight paths from north or north-west to south or south-east. Nor'westers begin generally towards the latter half of February and may occur in almost any part of north-east India, but chiefly in south Bengal. They are practically unknown in November, December and January at Calcutta. In 27 years there have been at Calcutta 15 Nor'westers in February, 60 in March, 128 in April, 164 in May and 78 in June. The frequency of Nor'westers in south-east Bengal is somewhat greater. Occasionally the Nor'westers attain tornadoic intensity and a few of them may be real tornadoes.

Cyclonic storms and depressions.—These are experienced mostly during the period April to December, but are more frequent in May and October. In the month of April about 4 severe cyclones have affected the Bengal and Burma coasts during a period of 32 years. During the same period, the number of such storms has been 8 in May, 6 in October, 5 in November and 3 in December. The storms in these months originate about the centre of the Bay of Bengal and, after a northerly travel, reach the Bengal coast or recurve towards the Burma coast.

During the monsoon months June to September numerous depressions develop over the head of the Bay. These, however, travel westwards and affect the Burma coast only during their formation.

Cloud.—In winter the skies are generally clear, clouds appearing only at intervals when the western depressions travel as far east as north Burma. In the hot weather, cumulus or thunder-clouds are fairly frequent in the afternoon over the coastal districts, particularly over Tenasserim. The south-west monsoon is the period of very frequent low overcast skies over practically the whole route, July and August being the cloudiest months. The central districts of Burma are, however, decidedly less cloudy. In this season there is

very little diurnal variation in cloudiness except for a slight decrease occasionally in the forenoon. In the transition period from October to December there is a gradual decrease in average cloudiness with the withdrawal of the wet monsoon from north Burma southwards, heavy low clouds then extend up the coast only at intervals in association with cyclonic disturbances in the Bay of Bengal.

Minimum cloudiness occurs in the months of January to March along the Burma coast and in January along the Bengal coast. The height of the base of low clouds is usually above 500 metres during the period April to August. Later, whenever low clouds appear, this limit falls to 300 metres and in the winter months low stratus clouds at 50 to 150 metres are also seen occasionally.

Rainfall.—Although the main rainy season is from June to September, rain also falls in the latter half of May and in October along the whole route. June, July and August are the wettest months, with the heaviest rainfall in July. The average annual rainfall varies from 63 ins. on 85 rainy days at Calcutta to 146 ins. on 111 rainy days at Cox's Bazaar. Of these about 17 ins. fall during the rainy season, June to September, on 63 rainy days, at Calcutta; and about 112 ins. at Cox's Bazaar, the number of rainy days being 70. Little or no rain as a rule falls during the period December to February in Burma, except in the northern districts, where light showers are occasionally received during the later stages of the movement of the cold weather disturbances in northern India. Showers are of occasional occurrence in March and April, chiefly in the coast and hill districts. Widespread rain, mostly associated with thunderstorms, is of comparatively frequent occurrence in May in Tenasserim. Occasionally in this month also cyclone storms form in the Bay of Bengal and pass into Burma. These storms break up on crossing the Arakan Yoma, but the humid south-west winds in their rear pass up the river valleys and give general rain to the interior for some days after the disappearance of the cyclonic structure of the storm. The south-west monsoon brings almost daily rain in the coast districts from June to October and frequent rain in the interior. The precipitation is heaviest in Tenasserim and Arakan, where it occurs at the average rate of 1 to $1\frac{1}{2}$ inches a day at the coastal stations during the months of June to September. The rainfall is probably two or three times as large in amount on the coastal hills at elevations of 3,000 to 6,000 feet, but unfortunately there are no data available for these hills. The rainfall decreases rapidly in amount in passing from the Pegu coast to the central basin, where the rainfall is only from a fifth to tenth part of that in the coastal districts. It thence increases rapidly northwards towards the mountainous country which forms the continuation in north Burma of the Eastern Himalayas and the Assam hill ranges.

The rainfall diminishes markedly in October and usually ceases by the middle of November. The precipitation in this period frequently accompanies thunderstorms and may at times be continuous and heavy if associated with cyclone storms of the season in the Bay of Bengal.

Over the Burma section the average annual rainfall amounts are 203 ins. at Akyab, 99 ins. at Rangoon and 109 ins. at Bassein, the number of corresponding rainy days being 125, 122 and 125 respectively. During the rainy season June to September Akyab receives 170 ins., Rangoon 75 ins. and Bassein 86 ins., the average number of rainy days at the corresponding stations are 98, 92 and 94 respectively.

Visibility.—On the Dacca—Chittagong section, fog or mist is likely to be encountered on most mornings during the months November to March up to about 8 hours and occasionally later.

During the rainy season visibility is considerably reduced whenever rain is falling and is positively bad whenever the intensity of rain is moderate or heavy.

(b) RANGOON—SINGAPORE.*

The route from Rangoon to Singapore is either *via* Bangkok to Penang and Singapore or direct to Penang and Singapore.

Physical features.—The Tenasserim coastal strip forms a narrow tract of land stretching from the Siamese border to the Gulf of Martaban. In many respects it is like the Arakan Coast. It is nearly everywhere hilly or mountainous. The hills run north to south and consist of granite and, where the granite masses reach the sea, they form rocky islands. A large part of the region is covered with dense evergreen forests. Siam is, on the whole, a lowland country, lying between the Tenasserim Yomas on the Burmese border and the mountains of French Indo-China. Malaya has a backbone of high mountains, with several parallel ranges on either side. It lies in the equatorial region, and all the hilly parts are covered with equatorial forests. The climate being very suitable for the growth of the rubber tree, enormous areas of the country are now covered by rubber plantations. The principal ports of Malaya—Singapore and Penang—are both on islands, but the former is connected with the mainland by a railway and road.

Summary of important weather features.—Variation in rainfall is one of the most important features in the seasonal division of the year in Tenasserim and Malaya, but as the variation is due to the more uniform changes in the wind, the wind changes are usually spoken of when seasons are mentioned. There are four seasons which one can distinguish, namely, (i) the south-west monsoon, May to September, (ii) the north-east monsoon, November to February, corresponding with the winter of northern latitudes, and (iii) two short transition seasons. The times of commencement of the monsoons vary from year to year and also their beginning and end are usually not well-defined. The south-west monsoon is usually established in the latter half of May and ends in September. The north-east monsoon commences in late October or in early November and ends in March. There remain thus two transition periods, each of about one or two months in length, between the ending of one monsoon and the beginning of the other one, corresponding roughly with the equinoctial seasons.

The full force of the south-west monsoon is experienced on the west coast of Tenasserim during May to September. Although the wet season of the west coast of Malaya corresponds with the period of the Indian monsoon, the winds of the south-west monsoon as experienced in the west coast of Malaya south of Alor Star are usually very light and at the ground are almost completely lost in stronger local circulations such as the land and sea breezes which are a regular feature.

The full force of the north-east monsoon is experienced on the east coast of Malaya south of Prachuab-Kirikai during November to January which is a period of definitely wet and stormy weather on the east coast. The effect of the north-east monsoon on the western route is comparatively less marked. During the transition period of October and the first half of November both the east and the west coasts of Malaya and Tenasserim are affected by cyclonic storms in the south-east Bay of Bengal or typhoons from the China seas (3 or 4 per year).

*The meteorological details for the Malayan portion of this route have been obtained in large part by the courtesy of the London Meteorological Office.

This route is liable to frequent thunderstorms and 'Sumatras' during March and April. Sumatras are a type of violent short lived squalls which are often associated with thunderstorms and torrential rain and which are experienced on the west coast of Malaya during the period April to September, fuller details are given in a later paragraph. Sumatras are most frequent during the night whereas the Nor'westers of Bengal occur mostly in the late afternoon and evening.

There are no marked seasons over the section of the route Penang to Singapore. A north easterly wind commences late in October or November and continues until sometime in March and is known as the north east monsoon. This is probably due to a southerly movement of the north-east trade winds of the China Sea rather than to what is usually understood as a monsoon effect. From May to August a light south-westerly wind blows. This wind is not strong and at the surface is entirely overpowered by the land and sea breezes. In the upper air, however, the general drift is from the south west. This south-westerly current does not blow across the whole length of the Peninsula like the north-east monsoon, but only extends southward to the region of Malacca on the west coast and to Pekan on the east coast. South of this the prevailing direction is south-east, the air stream arriving from south of the equator. The interval between the cessation of the north east monsoon and the commencement of the south-west monsoon is usually about eight weeks and there is a similar interval between the end of the south-west monsoon and the beginning of the north-east monsoon.

Thunderstorms are of frequent occurrence at all times of the year and fog often occurs over the land in the early morning.

Relative humidity is generally moderately high, about 80 per cent and over, except at Bangkok and its neighbourhood where it is somewhat lower during the north east monsoon. It is also probable that in the lee of high lands it is appreciably lower.

Air temperature.—During the winter months, November to February, the mean temperature varies between 77° and 82°F ., December and January are generally the coolest months. The average daily range is about 15° to 25°F ., in the northern part of the route, and 15° to 18°F ., at Penang, and temperatures sometimes reach as high a value as 91°F .. During the hot season, March to May, the mean temperature rises, and at Bangkok averages about 86° or 87°F ., over the isthmus, however, lower figures between 81° to 83°F are recorded. The sea breeze has usually a moderating effect, and in the neighbourhood of the coast the thermometer seldom rises to 100°F . At Bangkok, the temperature occasionally reaches as high as 106°F . The average temperature during the south-west monsoon (June to September) and in October is about 80° to 82°F ., though away from the coast line and in the lee of mountains higher temperatures may be reached. The diurnal range varies from 9°F . in the north to about 18°F . in the south. Even on the hottest day, the thermometer seldom rises above 95°F .

Over the portion of the route from Penang to Singapore, the mean surface temperature is fairly uniform throughout the year and varies from about 78° to about 82°F ., according to locality. The diurnal range averages from 15° to 20°F ., inland but is somewhat less near the coast.

The mean maximum and the mean minimum temperatures in the different months of the year as well as the highest and the lowest values attained at the principal stations along this route have been given in the table on the next page.

AIR TEMPERATURE. (°F.).

Stations.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Highest.	Lowest.
Pavoy	80 65	91 68	93 71	94 75	89 75	86 75	83 74	83 74	84 74	88 74	88 70	88 66	100	48
Mergui	88 68	89 70	91 73	92 74	89 74	86 74	85 73	84 73	84 73	87 73	87 71	87 68	99	43
Bangkok	92 67	93 70	95 73	97 76	96 76	93 76	92 76	92 76	91 75	91 75	89 71	89 67	100	52
Alor Star	91 71	94 70	94 73	92 74	90 75	89 74	88 75	88 74	87 74	87 74	87 73	88 73	99	62
Penang	90 73	91 73	92 74	91 75	90 74	90 74	89 73	88 73	88 73	89 73	88 73	89 73	98	65
Kuala Lumpur	90 71	91 72	92 73	91 73	90 73	90 72	90 71	90 71	90 72	89 72	89 72	89 72	98	66
Singapore	89 73	88 73	88 74	88 75	89 75	88 75	88 75	87 75	87 75	87 74	87 74	87 73	97	66

Surface winds.—From November to February, surface winds are generally between north and east. Between Rangoon and Bangkok they are usually light, but to southward of the latter place and along the eastern shore of the Malay Peninsula they are stronger and are strengthened by the sea breeze near the coast during the afternoon. On the eastern shore of the Isthmus the north-east monsoon brings with it heavy squalls and gloomy weather, and it is reported that over south Siam the monsoon is very strong when at its greatest intensity. On the western side of the peninsula, however, the strength of the north-east monsoon is considerably reduced by the intervening high land. While the sea breeze reinforces the monsoon on the east coast, on the west it retards the monsoon and tends to give lighter winds by day than by night.

South of Mergui, the winds are light and variable in the early months, but tend to become more and more easterly as the season progresses. Pronounced land and sea breezes prevail on the coasts. In the hot season winds are generally light and somewhat variable, but tend to become more westerly as the season progresses. On the coast, land and sea breezes continue to be the marked features.

In the northern part, winds are mainly west-south-westerly during the monsoon and blow with moderate velocity over the open sea and coast and comparatively lightly inland. During rain-squalls strong gusts with very bumpy conditions may be experienced. In the southern parts, winds are generally variable, and land and sea breezes are the predominating features on the coast.

After the monsoon, winds again become light and variable and land and sea breezes become the marked features on the coasts.

The month of October, when the south-west monsoon is giving way to the north-east monsoon, is one of squally, variable and uncertain weather over the Gulf of Siam.

Over the portion of the route Penang to Singapore, winds are usually light and variable during November to April, but the tendency is to blow from a northerly direction. Calms are of frequent occurrence, especially at night, but sometimes moderate squally winds accompany thunderstorms. On the coast, land and sea breezes prevail. During May to October, winds, though generally light and variable, blow from a southerly or south-westerly direction between Penang and Malacca and from between a southerly and south-easterly

direction between Malacca and Singapore. Along the coast, land and sea breezes are the marked features. During thunderstorms strong squally winds may occur.

Sumatras.—Over the straits of Malacca there occur during the season May to October storms of the type known as Sumatras. These are squalls from the south west. A greater number is experienced between Malacca and Penang than between Malacca and Singapore. Sumatras always occur at night, generally between 21 hrs and 3 hrs, and are nearly always accompanied by thunder, lightning and torrential rain. The strength of the wind is generally from 65 to 90 km./hr. The squall is always accompanied by its characteristic cloud formation—a heavy arch or bank of cumulonimbus—which rises to a great height and rapidly spreads over the entire sky. On many occasions changes in the wind direction take place, the wind shifting from south to west or north west, at the same time the speed increases from about 15 km./hr. to about 50 or 60 km./hr. The duration of these Sumatras seldom exceeds two hours. They do not appear to travel far inland, for they are mostly dissipated at a distance of 30 miles from the coast. Sumatras may occur simultaneously along a long line, sometimes as much as 200 miles in length running roughly from north west to south-east, the whole squall line travelling in an easterly direction at a speed corresponding to the speed of the squall wind.

Northwesters also occur most commonly during this season. These winds are sometimes severe at their commencement, but their strength abates after a short period. They are generally preceded by a black cloud arch which rises rapidly from the horizon towards the zenith.

Upper winds: Rangoon to Penang.—In January and February the winds are mainly northerly to easterly over the whole section at 0.5 and 1 km. Near Rangoon, they are south easterly to southerly at 2 km. and southerly to north westerly at 3 km. but, over Tenasserim and Malay, they continue to blow from some easterly direction. The wind velocities are of the order of 10-30 km./hr. and are comparatively weaker near Rangoon than farther south.

In March and April, the winds at 0.5 and 1 km. near Rangoon are mainly from a southerly to south-westerly direction. They are variable at 2 and 3 km. with a tendency to veer towards the west. In Tenasserim, the winds are generally weak and indefinite in direction up to the height of the hills, but become easterly at higher levels. The second half of April is a transition period in Tenasserim when the easterly upper winds change to westerly. The transitional nature of the upper winds continues in the first half of May. The winds gradually change to a southerly and south-easterly direction in Malay, south-westerly in Tenasserim and south-westerly to north westerly near Rangoon. The winds are variable at all flying levels, and are generally light to moderate, but may become strong in connection with cyclonic storms and advances of the monsoon.

In the monsoon months, June to September, the winds blow more or less steadily from the south-west in Tenasserim. The average speed is 30-60 km./hr. in July and August and somewhat smaller in June and September. Between Victoria Point and Penang, the direction alternates between south west and south east, depending on the strength of the monsoon. October is again a transition month especially for the northern half of the route. The winds near Rangoon are easterly to north easterly at 0.5 and 1 km. and easterly to south easterly at 2 and 3 km. In Tenasserim, the winds vary from the west to south-west of the south west

monsoon to the easterlies of November. November and December are the north-east monsoon months when the wind directions from Rangoon to Victoria Point are mainly from some easterly direction. The mean speeds are light to moderate near Rangoon, and generally moderate near Victoria Point. In connection with cyclonic storms, which in this season either form in the Bay or cross over westwards from the China Sea, winds of hurricane force may occasionally be experienced.

Penang to Singapore.—A single year's observations of upper winds at Kuala Lumpur and Singapore show a preponderance of northerly winds up to 1·2 km. above Singapore between December and March and variable winds above; but that, at Kuala Lumpur, the steady layer, with a prevailing north-easterly direction, extends to a greater height, up to 2 or 2·5 km., and above that the variable layer is reached. In November and April there are no very marked prevailing winds at either place, though westerly winds are somewhat the most frequent specially at Singapore. The observations on Cameron's Highland (1560 metres) show that at that level north-easterly winds are the predominant feature between December and March and winds of gale force are occasionally recorded. In November and April winds are generally uncertain, but southerly and south-easterly winds are most frequent in the former months.

Between May and July, the prevailing winds are southerly or south-westerly at both places up to 2·5 km. In September and October winds are variable. At Cameron's Highland, the predominant wind is between south-west and north-west from May to October.

Thunderstorms and squalls.—In the months, November to May, large cumulus or cumulonimbus clouds tend to develop in the afternoons and sometimes thunder is heard. As the season progresses the frequency of thunder increases from north to south. Indeed, south of Mergui up to Tung Song thunder is heard in the hot season on more than 20 days on the average in a month. Thunderous conditions continue south of Mergui even during the monsoon and post-monsoon months.

FREQUENCY OF DAYS OF THUNDER.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Rangoon . . .	0·0	0·4	0·2	1·8	0·4	5·4	4·4	5·6	3·8	0·0	2·0	0·4
Tavoy . . .	1·6	1·2	0·3	8·8	11·2	2·6	2·0	1·2	5·0	11·2	4·0	0·8
Mergui . . .	1·8	5·5	14·0	15·3	23·4	17·6	0·7	7·0	0·7	17·1	12·8	4·0
V. Point . . .	3·5	5·0	17·4	26·3	22·1	12·3	13·4	0·8	8·8	14·4	14·7	0·0
Bangkok . . .	0·1	1·6	4·3	7·3	14·0	8·0	0·0	8·6	11·0	7·0	9·8	0·0
Tung Song . . .	2·5	2·2	14·2	23·7	25·2	18·0	14·6	10·2	17·0	10·8	15·4	5·8
Alor Star . . .	3·0	7·0	15·5	21·0	11·0	12·0	12·0	8·5	2·5	0·0	5·0	8·0
Kuala Lumpur . . .	10·8	6·8	10·0	20·4	15·6	11·8	10·0	10·3	15·4	15·8	10·0	10·8
Singapore . . .	8·0	0·0	13·0	17·3	11·7	11·3	12·3	0·0	12·7	13·7	15·0	14·7

In association with cumulus clouds that form day by day, specially over broken country, marked bumps may be encountered.

Conditions are very turbulent and bumpy during early monsoon showers and squalls. Thunder is very frequently heard over the section Penang to Singapore, especially in the months of November, March and April.

Storms and cyclones.—Storms and cyclones forming in the Andaman Sea in April, May, September, October and November and also the typhoons which enter into the Bay of Bengal from the Gulf of Siam in these months cause

highly disturbed weather over the route, Rangoon to Ponang. Storms and cyclones which form in the middle of the Bay of Bengal generally travel toward the Burma Coast in the months of April, May, November and December and occasionally in the month of October and these when near the Burma Coast might cause disturbed weather in the northern part of the route from Rangoon to Ponang.

Cloud.—During November to February, cloud amounts are generally small between Rangoon and Bangkok, the mean amount being 3 to 6. South of Rangoon, however, the sky becomes progressively more cloudy and in northern Malaya about half the sky is cloudy. The cloud is chiefly of the cumulus or stratocumulus type, which forms especially during the afternoon along the coast and over the mountains. It is recorded that the mountains of south Siam though generally free of cloud up to about 13 hrs. are sometimes covered for days on end during the beginning of the north-east monsoon, November and December.

CLOUD AMOUNTS.

(Scale 0—10)

Stations.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Rangoon	9.0	2.8	9.0	1.1	7.3	8.0	9.2	0.1	8.0	0.5	1.5	3.5	5.0
Meikul	2.1	2.8	2.7	3.3	5.1	6.0	6.8	0.0	6.3	6.0	3.0	3.8	4.5
Y. Point	4.0	0.0	1.0	5.0	0.8	7.0	7.7	7.1	7.3	0.7	3.0	5.5	0.1
Bangkok	2.0	2.7	3.0	3.8	5.7	5.8	6.3	6.0	6.0	5.0	3.2	1.0	4.4
Alor Star	5.1	1.7	5.0	0.2	0.0	0.7	7.0	0.8	7.1	0.0	0.2	0.6	0.8
Penang	1.2	4.3	4.7	5.1	5.4	5.1	5.1	5.6	5.3	0.0	5.3	5.1	5.2
Canton's	7.0	0.0	0.0	7.4	7.3	7.0	7.5	7.5	7.0	8.3	3.1	3.0	7.5
Highland													
Kuala Lumpur	0.2	5.7	0.2	0.0	0.5	0.3	0.3	0.7	7.1	7.5	7.2	7.0	0.0
Malacca	0.7	5.0	0.7	0.3	0.0	0.0	0.0	0.5	7.0	7.0	7.3	7.0	7.0
Singapore	5.3	5.1	4.0	5.1	5.2	5.1	5.2	5.1	5.1	5.0	0.2	0.2	5.5

During the hot season, March to May, the amount of sky covered by cloud increases as the season advances and in May the sky is generally more than half covered by day. There is regular formation of cumulus clouds during the course of the day, though skies remain generally clear during night. These cumulus clouds often develop to a great size during the afternoons and may become cumulonimbus in which case they may persist after sunset. At the break of the monsoon, which may occur towards the end of May on the coasts of Burma and Siam, low cloud in association with the rain squalls that accompany the monsoon may prevail.

During the south-west monsoon, the mean cloud amounts decrease from north to south. At Rangoon the average amount of sky covered is about 9, while at Penang it is not more than 6. Stratocumulus and fractocumulus are the predominant types. During the monsoon squalls, cloud descends to very low altitudes. The mountains of Tonasserun and Siam are often enveloped in cloud at this season. To the eastward of the mountain boundary, cloud amounts are considerably less, and at Bangkok the average amount during the monsoon month is only 6. This decrease in cloud amount is probably maintained along the eastern side of the isthmus, but to south and south-west of Bandon large amounts of low cloud may be expected.

In the portion Penang to Singapore, there is usually a regular diurnal variation of cloud. The day breaks with a clear sky, but cumulus clouds develop as the day progresses. During the early part of the night these clouds tend to disappear and the sky is often cloudless by midnight, but on some occasions cloudy conditions may persist throughout the night.

Rainfall.—The south-west monsoon prevails over Burma and Siam and as far south as latitude 8°N. giving copious rain. South of that latitude the influence of monsoon winds is not so marked and rainfall rapidly decreases. Along the Burmese coast rainfall is exceedingly heavy but south of Victoria Point the amount of rain rapidly decreases. At Bangkok during April, frequent showers precede the real advent of the monsoon rains which occurs during the first fortnight of May, the onset being fairly sudden. The incidence of the monsoon varies considerably over the section of the route Rangoon to Penang (*via* Bangkok). Along the valleys of the Me Ping and the Taehin there is decidedly less rainfall than both to east and to west, and again along the eastern side of the isthmus very much less than on the western side.

MEAN RAINFALL AMOUNTS IN INCHES.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Rangoon	6.1	0.3	0.4	1.4	12.2	17.6	20.6	10.7	15.6	6.7	2.4	0.1
Pavoy	6.1	0.6	1.6	3.1	25.5	42.7	48.1	40.1	34.8	10.3	2.0	0.2
Mergul.	1.0	2.1	3.1	5.7	18.2	20.3	31.6	20.4	27.2	12.3	3.5	0.4
Victoria Point	0.3	0.0	0.7	4.7	22.0	26.2	31.3	27.2	23.8	14.7	6.1	1.1
Bangkok	0.4	0.8	2.4	2.3	7.8	0.3	0.3	8.0	12.0	8.1	2.6	0.2
Takuapa	1.1	1.8	0.1	7.5	17.7	20.5	23.8	23.0	33.8	21.2	0.2	3.1
Tung Song	5.0	2.1	5.7	7.6	7.6	0.1	0.3	0.8	10.7	12.0	13.8	8.3
Alor Star	0.7	0.8	4.3	5.7	0.0	12.0	4.4	8.3	8.7	17.3	7.1	13.6
Penang	3.8	2.0	4.7	0.0	16.8	7.7	8.3	12.8	16.1	10.6	11.8	5.0
Kuala Lumpur	6.6	6.0	8.8	16.7	8.4	4.0	4.6	6.2	7.6	11.1	10.0	6.0
Singapore	6.0	6.7	7.4	7.6	6.7	0.0	0.8	7.0	0.8	8.1	9.0	10.5

Between November to February, rainfall is comparatively small between Rangoon and Bangkok and between Bangkok and about latitude 11°N. Between that point and Penang heavy rain-showers are met with, especially on the windward side of high ground.

Visibility.—During November to April, early morning fog and mist often prevail in the river valleys and usually clear soon after sunrise. Between Bangkok and Bandon, visibility is expected to be good, when not limited by rainfall; but over the isthmus and southward to Penang, fogs and mists may occur occasionally and locally over rivers. Over the route Penang to Singapore fog or mist is very prevalent in the early mornings especially over low-lying ground and river valleys; at Kuala Lumpur it is reported to be occurring on nearly one in four days throughout this season, and at Klang and Johore even more frequently; coastal fog is, however, uncommon.

During the south-west monsoon season, May to October, visibility is usually moderate to good over the route Rangoon to Penang except when rain is falling, when the very intensity of rainfall may cause the visibility to fall to almost *nil*. Morning fog or mist over low lying land is rarely recorded in June, July and August and probably on not more than 3 days on the average in May, September and October. Over the mountains, visibility is often greatly limited owing to clouds covering mountain tops. It is reported that in south Siam fog often occurs after rain over the tops of the trees of dense jungle. Over the route Penang to Singapore, extensive morning fogs and mists are of frequent occurrence over low lying ground and river valleys during this season. For instance at Kuala Lumpur the average number of days on which fogs and mists are recorded is about 7 per month. On the coast extensive fog and mist are not common, though they may occur occasionally.

(c) CALCUTTA—DACCA—SHILLONG.

Summary of important weather features—This route lies through east Bengal and Assam and the remarks made in respect of the Bengal portion of the route, Calcutta to Rangoon, are applicable to this route as well. The following supplementary note is added:—

East Bengal, while exposed to moist winds from the Bay during more than half the year, is almost out of reach of the hot winds which blow down the Gangetic plain in April and May. Its climate is accordingly very damp and relaxing, and the reverse of that of north-west India. The cold season lasts from December to February, thereafter sea winds begin to blow from the head of the Bay, and during April and May give rise to frequent thunderstorms and Nor'westers. The rainy season proper begins in the middle of June and terminates at the end of October. The rainfall is irregularly distributed, it varies from about 70 to 120 inches from south-west to east and north Bengal. January is the coldest month with a mean temperature of about 64°F, and mean maximum temperature of about 77°F. The average afternoon temperature of the hottest months April and May is about 90°F, and upwards in all parts of east Bengal. In the central districts of Bengal, which occasionally come under the influence of hot winds down the Gangetic plain, the afternoon temperature averages about 100°F in April and 97°F in May. The establishment of the monsoon in June produces a moderate fall in the day temperature, but not till the end of October does the afternoon temperature range below 86°F. The nights are, on the whole, hottest in July and August, but the temperature varies very little from that month to October, after which it falls rapidly. The minimum temperature in the early mornings has fallen to 40°F, in deltaic and central Bengal and to 27°F, on the Khasi hills.

The climate of Assam is notoriously damp throughout the year. The humidity at 8 A.M. averages 90 per cent. of saturation and in no month does it fall below 75 per cent. The sky is seldom clear in the cold season. Thick fogs prevail, and rainfall is of occasional occurrence during the passage of cold weather storms across north-east India. Thunderstorms occur occasionally in March, and frequently during the succeeding two months, and in June merge imperceptibly into the monsoon rainfall which lasts until October. Little rain falls during the next two months, December, in fact, is the driest month of the year. The total rainfall recorded during the year over the province as a whole amounts to 100 ins., and of these 78 ins. fall from May to September. It exceeds 100 ins. in Sylhet and Cachar and at the foot of the Himalayas and is comparatively light along the southern margin of the Brahmaputra. At Cherrapunji in the Khasi hills the average for the year is about 400 ins. and even in the plains of Cachar and Sylhet some places record over 200 ins. Temperature is moderately high and fairly equable, with an average value of about 75°F. The coolest month is January with a mean temperature of 63°F, and the warmest July when the mean temperature averages 83°F. The average maximum temperature of the year is 84°F, and no reading higher than 106°F. has ever been recorded. The lowest mean temperature of the year is 60°F, at Sibsagar and 63°F at Dhubri and Silohar and nowhere in the plains has temperature fallen below 37°F.

Upper winds—In the winter months, December to February, the prevailing winds in the first kilometre are northerly to north-westerly near Calcutta, north-westerly near Dacca and weak easterly in the last part of the route. These easterly winds are due to the flow of cold air down the hills and are most marked in the early hours of the day. At 2 and 3 km., the winds are mainly north-westerly to westerly in the first two-thirds of the route, but in the last

third easterly winds are often met with even at 2 km. The wind speeds between Calcutta and Dacca are 15-20 km./hr. at 1 km., 25-35 km./hr. at 2 km., and 30-40 km./hr. at 3 km. Between Dacca and Shillong, the winds are generally weaker in the first $1\frac{1}{2}$ km.

In the months March to May, with increasing temperature in the interior of the country, southerly to south-westerly winds become more common in the first 1 or 2 km., but at 3 km. the prevailing direction remains westerly to north-westerly. Weak easterly winds are still encountered in the mornings in the first kilometre in the last third of the route. The wind speeds are on the average the same as in the winter but are stronger in the lower levels.

In the monsoon season, the winds blow from south to south-west near Calcutta at all levels up to 3 km., but near Dacca and beyond, south-easterly to easterly winds are more frequent than south-westerlies. The wind speeds do not generally show any increase with height. They are usually between 20 and 35 km./hr.

The latter half of September and October are the transition months in which the upper winds characteristic of the monsoon season gradually give place to those of the winter.

CHAPTER 4.

KARACHI—SRINAGAR AND HIMALAYAN ROUTES.

Physical features—This route passes over the lower Indus valley, a very dry alluvial plain depending almost entirely on and inundated by canals from the river Indus, over the Thar or the Great Indian Desert, and then over the Punjab plain, another very dry stretch of alluvium which depends almost entirely for agriculture on canals from the five rivers of the Punjab, and finally runs into Kashmir, situated amongst the mountains of north-west India. Between the middle and outer Himalayas, Kashmir is a valley different from most of the Himalayan valleys, it is broader, has a lake in it, and is 5,000 to 9,000 ft above sea level, the river draining it is the Jhelum. The Himalayan region can be divided into four belts according to vegetation and height above sea-level: (i) evergreen oak forest belt, 5,000 to 9,000 feet, (ii) coniferous forest belt, 9,000 to 12,000 feet, (iii) Alpine belt, 12,000 to 16,000 feet, (iv) snow, 16,000 feet to the top of the mountains.

The higher we go up, the poorer the vegetation becomes and at about 16,000 feet we pass the 'snow-line', above which the heat of summer is not sufficient to melt the snow which falls during the rest of the year, and so there is always snow.

Summary of important weather features—The first part of the route lies over Sind and the plains of the Punjab. This is on the whole the driest region in India, and is subject to extremes of heat and cold. Here the rainy season is very short, in the Punjab lasting only from about the end of June to the middle of September. Occasional rain is received in the first three months of the year, but its average amount is less than 15 per cent of that recorded during the prevalence of the summer monsoon. The total rainfall of the year is less than 5 inches round Jacobabad and 21 inches in the Punjab. Although on the mean of the year the hottest area in India lies over south and central Madras, the highest temperatures in India are recorded in the north-west dry area between June and September. June is the hottest month, with a mean temperature of about 95°F. and an average of about 105°F. in the afternoon; the absolute highest on record varies between 115° and 127°F. in the different districts. From December to January, the northern half of the route lies over a region which is the coolest in India. January has a mean temperature of only 59°F. and a mean minimum of 47°F. The diurnal range of temperature is very large on the average of the year and amounts to over 30°F. in Upper Sind.

The second part of the route lies over the Punjab and Kashmir. Precipitation in Kashmir occurs chiefly from January to April and from June to September. The summer monsoon discharges heavy rain on the face of the Himalayas. The total yearly amount however decreases from east to west, being 72 ins. at Chakrata, 64 ins. at Simla, 60 ins. at Murree, 26 ins. at Srinagar, and 30 ins. at Parachinar, it is only 3 ins. at Leh. In the valley of Kashmir, as represented by Srinagar, the mean monthly values of percentage saturation vary between 78 and 88. Temperature varies considerably from station to station; at Leh it ranges between 19°F. in January and 63°F. in July, at Srinagar between 34°F. in January and 75°F. in July, and at Dras between 3°F. in January and 63°F. in August. During the winter temperatures well below the freezing point are very often registered in the early morning in the hilly tract of Kashmir.

(a) KARACHI—JACOBABAD—MULTAN—LAHORE.

For Sind and the west Punjab, the year may be divided into the following seasons: (i) Winter—December to February; (ii) Spring and Summer—March to June; (iii) Monsoon—July and August; (iv) Autumn—September to November.

The periods of the different seasons given above represent only the average durations and are liable to variations from year to year and from place to place.

Surface winds.—The surface winds are more or less steady during the monsoon and to a smaller extent also in winter, but are variable and light in the other seasons except near Karachi, where westerly winds prevail. During the monsoon, when a trough of low pressure usually lies over north-west India, moderate to strong westerly to south-westerly winds prevail over the first portion of the route, and light to moderate south-easterly to easterly over a small section towards Lahore, easterlies or calms being experienced over the middle section. In winter the pressure over north-west India is relatively high and the winds are generally light variable to north-easterly, calms occurring quite frequently at places. During the passage of depressions and western disturbances, however, the usual flow of the wind no longer holds and both the direction and the velocity undergo considerable changes, depending on the variations in isobaric distribution.

Upper winds.—The seasonal region of high pressure over north-west India in winter and the trough of low pressure there during the monsoon in a general way control the upper winds, especially at lower levels, as well as the surface winds. In winter the upper winds are moderate to strong mainly north-westerly to northerly in the neighbourhood of Lahore and north-westerly to westerly near Karachi, where north-easterly components are quite frequent below 1 km. During the monsoon the winds up to 1 km. are moderate to strong westerly in the neighbourhood of Karachi, and variable, mainly between south-easterly and south-westerly, near Lahore; at higher levels the winds are generally moderate to strong between north and west near Lahore, and between north-east and north-west near Karachi. In the other seasons the predominating winds at all levels are northerlies or north-westerlies over the northern and central sections and westerlies over the southern section. When, however, the route is affected by a depression or a western disturbance, the upper winds, like the surface winds, deviate from their usual course and follow the new circulation.

Thunderstorms.—Thunderstorms are rather uncommon over the section Karachi to Jacobabad, but over the rest of the route they occur locally and occasionally during the period from mid-summer to mid-autumn, being most frequent during the monsoon season. Their occurrence during winter and spring is associated with western disturbances.

Cloud.—During the monsoon season, the mean amount of clouds of all kinds, high, medium or low, at 8 hre. (local time), varies from about 2 to 7. It is greatest over the Karachi-Hyderabad section and lowest over the Naushahro-Multan section, while over the Montgomery-Lahore section the mean cloud amount is 3 to 4. In winter cloudiness is most pronounced over the Montgomery-Lahore section where the mean amount is about 4, while over the rest of the route it is generally between 2 and 3. In summer the mean cloud amount generally remains about 2 over the whole route, while in autumn the sky is mostly clear. As an exception to this general statement, overcast skies may prevail for several days during wet weather associated with the passage of depressions, specially in the neighbourhood of Lahore.

Rainfall.—During most of the year the climate over this route is of desert type. October and November are the months of least rainfall. Rainfall is, however, seldom intense along the route even during the monsoon, (the highest average monthly total being only 5.48 ins. in July at Lahore), and it is scanty over the portion Naushahro (near Pad Idan) to Multan. The rainfall during the monsoon is generally associated with depressions, which form in the Bay of Bengal and, travelling across the country, break up in the frontier hills of Kashmir, in some rare cases, it may be very heavy over a large area, resulting in severe floods. During the winter and the early part of the spring, rainfall occurs under the influence of western disturbances which enter north-west India from the west across the frontier and travel eastwards, while, in the other months, it is generally associated with occasional thunderstorms.

Visibility.—The season of duststorms usually commences at the end of winter and continues up to the end of the monsoon season over the first half of the route and up to mid autumn over the second half. It is at its height during summer, when very severe duststorms sometimes occur over the route and particularly over the Naushahro-Multan section. Duststorms are infrequent during the period from mid-autumn to the end of winter and only a few are experienced during the passage of western disturbances.

Dusthaze usually occurs during summer and is more frequent over the northern portion of the route than over the southern. It is uncommon in winter and during the monsoon, but occasionally occurs during the autumn, particularly in the neighbourhood of Hyderabad and Lahore.

Fog occurs during winter and is most frequent in the neighbourhood of Hyderabad and Lahore, where every third or fourth day may be foggy. It is also quite frequent in winter near Karachi, Jacobabad and Multan. Fog sometimes occurs in mid-autumn and spring over the Karachi-Hyderabad section and in the neighbourhood of Lahore. Fog generally appears in the early morning and seldom persists beyond forenoon or midday.

During the occurrence of duststorms, dusthaze or fog and often during rain, visibility may be poor to bad (4 or less on the scale), generally however fair to good visibility may be expected. Visibility is generally poor over the desert in day time during April and May.

(b) LAHORE—SIALKOT—RAWALPINDI—SRINAGAR

Surface winds.—Surface winds at Lahore blow most frequently from a north or north-west direction during the winter months, but during the monsoon months, June to September, easterly or south-easterly winds are most frequent owing to the trough of low pressure over the Gangaotic plains and depressions from the Bay of Bengal moving northwestwards. Over the rest of the route winds are generally light at least in the mornings and are mostly easterly or south-easterly with a large percentage of calms.

Upper winds.—In the winter months, November to February, upper winds are mainly north-westerly in the first kilometre with speeds usually less than 25 km./hr. At 2 and 3 km., westerly and south-westerly winds are also common. With increase of height, the wind speeds also increase, velocities up to 50 km./hr. being not uncommon at 3 km. South-westerly winds occur when western disturbances lie over the North-West Frontier Province. In March, April and May, northerly to north-westerly winds are prevalent up to 1 km. In June, the winds are generally between west and north-west up to 2.5 km., the speed usually is in the neighbourhood of 25 km./hr., but occasionally goes up to 50 km./hr. even at lower levels. In the monsoon months,

July and August, the winds up to 1 km. generally come from south-east to south-west, the former direction being more common near the Himalayas. The wind direction changes to between south-west and north-west at 2 and 3 km. In September and October, with the withdrawal of the monsoon from the Punjab, the southerly winds at lower levels give place to weak westerly to north-westerly winds.

Thunderstorms.—Thunderstorms are most frequent over the route during the monsoon months. They occur on about 4 days a month in July and August at Lahore, 6 days a month from July to September at Rawalpindi, 7 days a month from June to August at Murree and on about 5 days in August at Srinagar.

Storms and depressions.—In some years depressions from the Bay of Bengal move to the Punjab and break up in the hills during the months of July and August. They may cause very heavy rain, reaching occasionally to as much as 5 to 10 inches; and give rise to severe floods, such as happened at the end of August 1928. On such occasional low clouds and heavy rain may continue to be experienced for 2 to 3 days at a time.

Cloud.—The months of July and August during the south-west monsoon period and the months of January and February during the winter months are the cloudiest months along the whole route. Owing to the influence of western depressions which pass more frequently over Kashmir and the north Punjab hills region, the average cloudiness is much higher in Srinagar during December to April than during July and August.

Precipitation.—As a rule the maximum amount of rainfall occurs during the south-west monsoon period (June to September) in the Punjab portion of the route. In Kashmir more rain or snow falls during the winter period of October to March than in the monsoon. At Srinagar snow falls on the average on about 4 days in December, on 6 to 7 days in January and February and on 2 days in March. Occasional snowfalls also occur in November and April. The average monthly rainfall and the average number of rainy days along the route during the whole year are given below:—

MONTHLY AND ANNUAL RAINFALL AND NO. OF RAINY DAYS.

Normal rainfall in inches printed in ordinary type.

Normals of rainy days printed in heavy type.

Station.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Lahore	1.05	0.94	0.88	0.54	0.70	1.63	5.48	5.38	2.36	0.25	0.07	0.86	10.02
Stalkot	2.11	1.59	1.68	0.94	1.13	2.40	7.80	8.91	3.87	0.80	0.11	0.66	28.1
Rawalpindi	2.40	2.19	2.44	1.04	1.34	2.24	8.4	8.1	8.8	0.7	0.8	1.2	31.02
Murree	3.73	4.14	4.87	4.21	2.87	3.88	11.84	14.88	5.01	1.50	0.77	1.57	48.8
Jammu	2.88	2.30	2.05	1.73	0.70	3.58	13.25	14.30	6.10	0.70	0.26	0.80	77.1
Srinagar	2.76	2.73	3.03	3.70	2.27	1.43	2.32	2.93	1.60	1.09	0.43	1.44	58.2
	5.9	8.2	8.0	8.4	5.3	8.6	5.0	5.8	8.5	8.8	1.2	8.8	58.8

The south-west monsoon reaches north Punjab and Kashmir usually by the second week of July and withdraws from there during the second week of August. These dates are, however, only the averages of many years and in any particular year the dates of commencement and withdrawal of the monsoon may be appreciably earlier or later than the above average dates. It will be seen from the Table above that the rainfall is greater in the neighbourhood of the Murree hills than over the rest of the route and that during the monsoon period, (June to September), July and August are the wettest months with the heaviest rainfall in August of about 5 ins at Lahore, 9 ins at Sialkot and Rawalpindi, 15 ins at Murree, 14 ins at Jammu and 2 ins at Srinagar; in June and September there is less rain. During the months of July and August, depressions from the Bay of Bengal sometimes move to the Punjab and cause locally heavy rain along the route continuously for 2 to 3 days.

During the winter period, i.e., October to March, the weather along the route is affected by western disturbances which generally travel from a westerly direction to an easterly direction across north-west India. These disturbances cause precipitation (rain or snow) along the route.

Although during the months of April and May the tracks of the western disturbances generally follow more northerly latitudes, they continue to affect the weather of the north Punjab hills and Kashmir. The precipitation contributed by these over this hilly area is quite appreciable. Over the plains of the Punjab precipitation in these months is usually associated with evening thunderstorms and averages little in amount. Heavy falls of 3 inches and over are more frequent on the route to the north of Lahore.

Visibility—During the months of July and August and also during the winter period (December to April) when the western depressions pass over this route the hill tops are likely to be mostly covered with clouds, and visibility may be poor to bad during rain. During the months of March to June when duststorms are very frequent over the north Punjab visibility is likely to be often poor to bad due to dust raised during a duststorm and sometimes even for one or two days afterwards due to thick haze. Early morning and late afternoon mist and fog are fairly frequent, especially in the valleys during the winter months.

(c) HARDWAR—CAUGHAR.

Summary of important weather features.—The summer monsoon which lasts from June to September discharges heavy rain on the face of the Himalayas, but does not penetrate to any appreciable extent into the interior.

During the cold season, which extends from December to March, weather is disturbed at intervals and moderate rain then falls in the submontane plains with moderate to heavy snow on the hills. At elevation of 8,000 to 7,500 feet in the Himalayas the coolest month is January with mean temperature between 40° and 43°F, and the warmest is June when the mean temperature ranges from about 65° to about 70°F. In the submontane districts the highest temperatures recorded are 111°F, at Dohra Dun and 115°F, at Roorkhee; and the lowest are 28°F at Roorkhee and 30°F, at Dohra Dun.

Surface winds—Owing to the mountainous nature of the region, the surface winds at each place are considerably influenced by local orographical features.

In the neighbourhood of Dohra Dun, winds are light and unsteady throughout the year. In the neighbourhood of Mussooroe, however, northerly to north-easterly surface winds predominate except in June to August, when the predominant winds are south-easterly to south-westerly.

Upper winds.—In winter upper winds are mostly north-westerly during settled weather and south-easterly to southerly when the region is affected by a western disturbance, becoming variable during the periods of change. In spring and summer north-westerly upper winds (generally inclined towards north at lower levels and towards west at higher levels) are most common, but under the influence of some late western disturbances or local unsettled conditions winds blow sometimes from south-east or south, specially at lower levels, and occasionally from other directions. South-easterly winds become common with the passing away of summer and are frequent in monsoon, but north-westerly winds remain pronounced only at higher levels in the first half of the monsoon, and become most predominant in the second half. During autumn north-westerly winds continue to be most common but early western disturbances and local unsettled conditions affect the region and south-easterly winds are also fairly frequent, while winds blow occasionally from other directions.

Storms and squalls.—Thunderstorms are most frequent during summer and monsoon and fairly common in the second half of winter and the first half of autumn, occurring only occasionally during the rest of the year.

Gales are occasionally experienced in summer and are mostly associated with local disturbances.

Squalls are mostly associated with thunderstorms and occur in the higher parts in all the twelve months and in the lower parts mainly from mid-winter to mid-monsoon but comparatively less often than in the higher parts.

The frequency of thunderstorms observed at the meteorological stations in the region in each month during 1931, 1932, and 1933 is given in the table on page 33.

Cloud.—The mean amount of clouds of all kinds—high, medium and low—in the morning is between 7 and 9 during July and August, about 3 to 5 during December to March and June and September and less than 3 during the other months, *vide* table on page 33. These values, being only averages, are not to be taken to represent the actual cloudiness during spells of wet weather, when low clouds may prevail for several days at a stretch.

Precipitation.—Rainfall occurs over the region, more or less, in all the twelve months, but that during the monsoon is by far the most intense, being particularly heavy and frequent during July and August; the rainfall associated with well-marked depressions, forming in the Bay of Bengal and travelling westwards or north-westwards across the country, may be continuous over large areas for several hours and very heavy at places. In the winter months, under the influence of western disturbances, which enter north-west India across the frontier and travel eastwards, comparatively less frequent but fairly intense and prolonged spells of wet weather prevail and large accumulations of snow may sometimes occur over the hilly regions. The rainfall in the other months is generally associated with local thunderstorms, except occasionally during spring when some late western disturbances may affect the region.

Mussooree, Dehra Dun, Lansdown and Okbimath are comparatively wet places, Mussooree being the rainiest with an annual normal precipitation of 110 inches.

Snow and sleet.—Snow or sleet occurs in the higher parts during winter being most frequent in February.

Hail—Hail occurs fairly frequently in winter and mid-summer and occasionally in autumn, but is uncommon during the monsoon. The occurrence of hail is more frequent in the higher parts than in the lower

Ground frost—Ground frost in the higher parts begins to appear in the second half of autumn and is very frequent in winter, sometimes occurring daily for a whole month. In the other seasons it is uncommon. In the lower parts also it occasionally occurs during winter and may in some years be fairly frequent.

The frequency of snow or sleet, hail and ground frost observed at the meteorological stations in the region in each month during 1931-33 is given in the table below.

Visibility—Duststorms occur only occasionally during summer over the lower parts. Dusthaze occurs occasionally during summer, but in some years it may become fairly frequent before the onset of the monsoon.

In the higher parts fog appears frequently during the monsoon and occasionally in other seasons. In the lower parts occasional fog is observed in the monsoon season.

In the higher parts visibility is very variable during the monsoon, when, due to the frequent occurrence of fog and during heavy rain or thick drizzle, it is more often poor to bad than fair to good, being sometimes less than 200 yards. Poor to bad visibility may also be experienced during the occurrence of snow or sleet in winter and due to occasional mist or haze at other times, but on the majority of days in the seasons other than the monsoon visibility is fair to good. Over the lower parts visibility is occasionally poor to bad during the period from mid-winter to the end of monsoon, otherwise fair to good.

Frequencies of different visibilities, of duststorms, dusthaze, and fog, observed at the meteorological stations in the region in each month during 1931-33 are given in the table below.

HARDWAR—GAUCHAR ROUTE.

Stations	Jan	Feb.	Mar	Apr	May.	Jun.	Jul.	Aug.	Sep	Oct	Nov.	Dec
Frequency of Thunderstorms.												
Dehra Dun	1 0	3.7	1 3	3 7	10 3	8 3	11 7	13 8	10 0	4.7	3.7	...
Mussoorie	0 7	2 7	2 0	3 0	7 0	5 3	2 7	3 7	8 0	2 7	0.3	0.3
Mukteswar	1 0	2 3	1 7	0.3	8.0	7 0	1 7	1 0	1 7	1 3	0.3	1 0
Mean cloud amount at 8 hrs.												
Dehra Dun	1 3	1 0	7 5	2 8	2 2	1.0	7 5	8 2	4 7	1.0	1.5	0.1
Mussoorie	3 0	3 7	2 0	2 0	2 7	4 3	7 7	7 8	4 8	1.1	1.2	2 0
Mukteswar	3 3	3 3	3 7	2 0	2 3	5 5	8 2	8 5	5 4	2 3	1.5	2 7
Frequency of snow or sleet.												
Dehra Dun	..	..	...	..	..	..	..	..	..	..	..	..
Mussoorie	0 3	2.3	0.7	..	..	..	..	..	..	..	..	1.3
Mukteswar	2 3	5 7	0 7	..	..	..	..	..	..	..	..	0.7
Frequency of hail.												
Dehra Dun	0.3	0.7	0.3	0.3	1.0	0.3	...	...	...	...	0.3	..
Mussoorie	1.0	3.0	2 0	0.7	2.0	0.3	...	...	...	1.0	0.3	2.7
Mukteswar	1.3	0.0	2.7	...	1.7	0.3	...	...	...	...	..	1.7

Stations.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Frequency of ground frost.												
Dehra Dun	1.0	3.0	...	...	...	...	...	...	...	...	...	1.0
Mussooree	9.0	4.0	...	...	...	...	...	...	...	...	0.8	5.8
Mukteswar	21.0	18.3	3.7	...	...	...	...	...	...	...	7.0	10.8
Frequency of duststorms.												
Dehra Dun	...	...	...	0.3	0.3	...	...	...	...	...	...	...
Mussooree	...	...	...	...	0.3	...	...	...	...	...	...	...
Mukteswar	...	...	...	...	...	...	...	...	...	...	...	...
Frequency of haze.												
Dehra Dun	...	...	...	1.0	...	3.7	...	...	...	...	...	...
Mussooree	...	...	...	...	...	0.7	0.8	...	...	...	...	...
Mukteswar	...	...	...	...	...	2.8	...	...	...	...	...	...
Frequency of fog.												
Dehra Dun	...	...	...	...	...	...	0.3	0.7	0.8	...	...	...
Mussooree	0.3	0.7	...	...	1.0	0.7	3.3	13.7	0.7	1.7	...	0.7
Mukteswar	0.7	0.8	...	1.7	0.7	2.0	0.0	0.3	4.0	1.0	0.8	...

Percentage frequency of visibility at 8 hrs.

	0	1	2	January—February.					3	4	5	6	7	8	9	0	1	2	3	April—May.					4	5	6	7	8	9
Dehra Dun	1	...	...	1	...	8	32	30	10	...	...	...	1	5	1	23	40	1										
Mussooree	1	...	...	1	...	7	15	14	61	...	...	...	1	1	2	6	11	27										
Mukteswar	2	1	1	1	1	2	31	60	6	...	1	...	...	1	8	3	47	62										
	0	1	2	July—August.					3	4	5	6	7	8	9	0	1	2	3	October—November.					4	5	6	7	8	9
Dehra Dun	1	...	...	...	10	32	60	6	...	...	...	1	...	...	...	1	...	...	...	...	1	0	04	20				
Mussooree	10	10	6	10	8	10	6	4	27	...	1	1	...	1	...	...	1	...	...	...	...	2	2	0	8			
Mukteswar .	7	28	8	1	11	8	11	10	10	...	1	2	...	1	...	...	1	...	...	...	...	4	15	44	39	80		

(d) AIR ROUTES IN AND TO THE NORTH-WEST FRONTIER.

Physical features.—This region comprises the tract on the west of the Indus; and consists of a series of three plains—Peshawar, Bannu and Dera Ismail Khan—divided from one another by the low hills of Kohat and offshoots of the frontier range, and Baluchistan, which is a plateau with a very irregular surface, averaging from 1,000 to 3,000 ft. in height and cut off from India by the Sulaiman range. Except near the coast, Baluchistan forms an area of inland drainage. The rivers flow into shallow lakes which often dry up in the hot weather. The Bolan Pass is the easiest route from Baluchistan to India, and the town of Quetta lies at the head of the pass. The Indus valley itself is a fine tract, the valley of Peshawar is highly irrigated and all well wooded. Where irrigated the Bannu Plain is fertile but elsewhere is dry and barren. The plain of Dera Ismail Khan is a clay desert, but in good rainfall years it becomes grass covered. Peshawar is the most important town of the North-West Frontier Province and controls the route through the Khyber Pass.

Summary of important weather features.—Judging from the main meteorological conditions prevalent over the extreme north-western part of India, the year over the north-west frontier may be broadly divided into two main seasons, winter and summer. During the former period, the great anticyclonic system extending from Siberia to Persia determines the normal pressure distribution over the region in question. The pressure gradient runs roughly from north to south, and winds blow normally from some north-westerly direction up to great heights. In the middle of April a reversal of the pressure gradient begins to take place, and by June a vast low pressure area stretching from north-west India to Arabia induces the monsoonal weather conditions

over the Indian Ocean and the Indian Peninsula. Under the influence of the above seasonal low over north-west India, and the consequent pressure gradient from south to north, an oceanic current slowly reaches north-west India and causes cloudy skies and copious precipitation.

While the year may thus be broadly divided into two main seasons, hot and cold, there are actually two other periods marking the transition from cold to hot weather and *vice versa*. Meteorologically, the year over the frontier may thus be classified into four seasons—(i) Winter period—December to mid-April; (ii) Transition period—mid-April to June, (iii) Summer (Monsoon) period—July to September, (iv) Transition period—October and November.

In winter, a succession of depressions from the west travels across the high pressure region over Central Asia. They generally pass through Persia and Afghanistan, cross the frontier and enter the plains of north-west India. The passage of these depressions across the frontier, about five or six times on the average each month, causes marked variations of weather over this region during the winter period.

Normally, these winter depressions make their first appearance over the frontier about the middle of October, but owing to their passage through regions of higher latitudes, such as north Afghanistan and the extreme northern borders of the frontier, they do not at first cause unsettled weather except occasionally over the Chitral area, the northern half of the North-West Frontier Province and in Kashmir. During the winter period, December to mid-April, they begin to pursue a more southerly course, are more frequent and generally more active. In the transition period, mid-April to June, they begin to recede again to higher latitudes and are less active, usually causing only localised disturbed weather associated with turbulent phenomena such as duststorms and thunderstorms.

In summer, an occasional advance of the south-west monsoon from the Arabian Sea or a deflected current from the Bay of Bengal causes cloudy weather and rainfall over the frontier. The advance of the monsoon is usually associated with the westward moving disturbances from the Bay of Bengal which sometimes merely cause an orientation or intensification of the seasonal low over north-west India. At other times they travel as fully formed depressions with well defined fronts marking the discontinuities between two or more samples of air. These depressions often begin to weaken during their westward march and generally lose much of their activity by the time they reach Central India or Rajputana. On a few occasions, however, they continue to be active and travel into the Persian area through Baluchistan, and sometimes recurve north-east or northwards from Rajputana and break over the Western Himalayas or the Kashmir hills. Except on such occasions, when the frontier region experiences fully prolonged unsettled weather, the precipitation over this area in the summer season is usually in the nature of thunder-showers and occurs in the afternoon or early evening when convection is most marked.

Surface winds—Owing to the hilly nature of the frontier, the large diurnal range of temperature, and great changes in pressure gradient, there is a complex variation in the surface winds during the year. In settled weather, katabatic and anabatic winds are very common, particularly the former. Associated with the passage of depressions, squalls and occasional gales occur during the winter and in early spring. During the hot weather, duststorms are experienced over all parts of the frontier, but are less frequent in the extreme north. Hot Föhn winds occur periodically in the North-West

Frontier Province from May to September and the 'Scistan' wind of south-east Afghanistan is felt in north Baluchistan as a strong dust-raising wind. Dust-whirls are a common spectacle in the enclosed plateaux of north Baluchistan and are also seen occasionally in the plains of the North-West Frontier Province.

Upper winds.—Throughout the year the normal direction is between north and west, tending to become stronger and more westerly with increasing height. With the approach of depressions from the west the upper winds first back towards south-west by south-east, and later change to north-west by west or north-east by east according as the path of the depression is to the north or the south respectively. With the occasional extension of the monsoon current into the frontier districts the upper winds have a marked easterly component which disappears as the current recedes again.

Storms.—Snowstorms occur at frequent intervals in the extreme north from December to March. Thunderstorms and occasional hailstorms occur in the spring and summer months, generally in the early evening or at night, see frequency table below:—

MEAN MONTHLY FREQUENCIES OF THUNDERSTORMS.

Stations.	Year.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
North-West Frontier Province.													
Peshawar	7	0.1	0.0	0.4	1.6	1.1	1.2	0.4	1.1	0.0	0.7	0.0	0.0
Cherat	18	0.2	0.6	0.9	2.9	2.6	1.8	2.9	3.0	2.4	1.5	0.1	0.0
Parachinar	24	0.1	0.2	1.4	8.2	8.7	4.1	8.8	2.2	8.5	1.7	0.8	0.1
Baluchistan.													
Fort Sandeman	13	0.1	0.1	0.6	0.5	0.9	2.6	2.7	2.3	2.4	0.6	0.2	0.1
Quetta	7	0.0	0.1	2.1	2.1	1.0	0.7	5.0	1.4	0.4	0.0	0.0	0.1

Duststorms, which occur as a rule in the afternoons and evenings, are most frequent (4 to 5 per month) in May and June. They are also experienced in the North-West Frontier Province and Waziristan in July and August and occasionally in September. These storms are most vigorous and occur most frequently in south Waziristan and the Zhob Valley.

A tornado of moderate intensity has actually been observed and photographed at Peshawar but such a phenomenon is of rare occurrence in this part of India. Apart from storms, turbulence associated with vertical currents and eddy-motion in the atmosphere causing 'bumpiness' is most pronounced in the afternoons, especially over and near hills or uncultivated ground, and particularly in the hot weather. Marked turbulence is also felt in the immediate rear of active depressions, when strong descending currents may be experienced.

Cloud.—Similar remarks apply to cloud as to rainfall. The amount of cloud is greatest in the winter months and in the monsoon season, but diminishes from north-east to south-west. Skies are generally clear or lightly clouded in May, June, October and November. Low cloud of the cumulus and cumulonimbus type is very frequent over the hills during the hot weather, particularly in July and August over the North-West Frontier Province. The condensation of water-vapour from ascending currents caused by local convection and its gradual exhaustion with precipitation on successive ranges is very obvious during the monsoon season in the Hazara and Black Mountain

Country, the windward face of each range being clothed day after day with a white crest of cloud whilst the slopes on the lee side are often left entirely free. Diurnal variation is well marked over the whole of the frontier, there being a tendency for clouds to decrease during the forenoon and after sunset.

Precipitation—The total annual fall of rain gradually increases in quantity as we pass along the frontier from south-west to north-east, *i.e.*, the rain is heavier as we approach the Himalayas. The winter precipitation commences earlier in the north than in the south and also ends later. Snow falls on about 3 days in January and February and on about 2 days in December and March. Occasional falls also occur in November and April. The limit of the snow line in winter is about 7,000 feet, although it sometimes lies for a few days at 6,000 feet. Actually snow has been known to fall at Peshawar. In summer the snow-line recedes to 15,000 feet or more. The amount of rainfall is relatively small over the whole of the frontier in May and June and again in October and November. During the monsoon season, heavy falls of rain occur in the extreme north, the amount diminishing as we move westwards and southwards away from the Himalayas.

Visibility—Visibility remains very good for almost the whole of October and November, deteriorating occasionally owing to haze. From December to April it often becomes very poor owing to low clouds caused by the passage of depressions. During the fine spells between these depressions, however, visibility is remarkably good and landmarks stand out with great clearness. In the hot weather visibility deteriorates owing to dust-haze and duststorms, and is at times exceedingly bad over the plains and plateaux of the frontier. The haze often becomes so thick in parts of the North-West Frontier Province and Waziristan that for days at a time it is not possible to make cross country flights, and even local flying may be very restricted. During the monsoon months there is an occasional improvement after rain has fallen over north-west India. Throughout the year there is a tendency for visibility to improve in the middle of the day.

CHAPTER 5.

BOMBAY—CALCUTTA ROUTE.

Physical features.—The following two alternative routes may be adopted :

(a) Bombay—Jubbulpore—Allahabad—Calcutta.

(b) Bombay—Nagpur—Calcutta.

A large part of the former route passes over the great plain of northern India and the main features over that part have already been described. The latter route passes over the narrow coastal plain and the slopes of the Western Ghats and then over the northern part of the plateau of peninsular India. The surface of this plateau is by no means smooth. It is deeply furrowed by river valleys, and towards the north a very important line of mountains runs across the plateau from west to east. These mountains are the Satpura range, continued eastwards as the Mahadeo hills and the Maikal range. There are two other lines parallel to the Satpura range—the Vindhya range to the north and the Ajanta range to the south. Northwards the plateau slopes down towards the great plain of northern India. The north-eastern plateau is a complex region comprising the Central Indian highlands, the Chota Nagpur plateau (2000 to 2500 ft. high) and the Chattisgarh plain or Mahanadi valley. Finally the route passes over the deltaic Bengal.

Summary of important weather features.—In the central parts of the country, the dry season begins in the first half of October and lasts until the second week in June. Occasional light rain occurs during the period, being associated in January and February with winter storms and from March to May with dust-storms and thunder-storms. The total rainfall recorded during the year averages a little over 41 ins. ; and of this, 37 ins. fall in the rainy season from June to September, 2½ ins. from October to December and nearly 2 ins. during the first five months of the year. The mean annual humidity is 56 per cent. In April and May, when hot westerly winds prevail, the percentage of saturation is only 29, but with the setting in of the rains in June, a rapid increase in humidity occurs, and during the next three months the air is almost saturated. The mean temperature of the year ranges from 81°F. at Chanda and Amraoti to 75°F. at Sconi and Jubbulpore. December is the coolest month, with a mean temperature of 65°F., and a mean maximum temperature of 80°F. and a mean minimum temperature of 52°F. The hottest month is May, with a temperature averaging 94°F. during the day, rising to 107°F. in the afternoon and falling to 80°F. in the early morning. The extremes of temperature hitherto recorded are 119.5° and 32°F.

Bihar and Orissa receives occasional light rain during the first two months from winter depressions. Precipitation is heavier during the next three months, but more specially in May, and is associated with thunderstorms and hailstorms. The monsoon rains appear about the middle of June and last till the middle of October in Bihar and Chota Nagpur and three or four weeks longer in Orissa. The annual rainfall averages nearly 58 ins. in Orissa, 52 ins. in Chota Nagpur, and 50 ins. in Bihar. Speaking broadly, about 90 per cent. of the total fall is received during the monsoon, and only about 10 per cent. during the remaining months. The driest month in the year is December with only 18 cents of rain, and the rainiest is July with an average fall of about 13 inches. On the mean of the year the humidity is lowest on the high ground of Chota Nagpur and thence increases both northwards and southwards, being greatest on the coast of Orissa. Near the coast the variation in humidity is small, the monthly

mean values at 8 hrs varying between 89 and 78, but at inland stations the range is large, thus the average humidity at Hazaribagh varies from 36 in April to 87 in August, and at Patna from 51 in April to 87 in August

The mean annual temperature varies from 82°F at Cuttack to 75°F at the elevated stations of Hazaribagh and Ranchi. May is the warmest month with a mean temperature between 84° and 93°F. In Orissa and Chota Nagpur, December is the coolest month of the year, but in Bihar, the January temperatures are slightly lower than those of December. The highest afternoon temperatures vary between 106° and 105°F. In Bihar, between 90° and 106°F. in Chota Nagpur and between 90° and 106°F. in Orissa. The absolute highest afternoon temperatures yet recorded vary between 102° and 110°F. The night temperature of the coldest months, December and January, averages about 51°F. in Bihar and Chota Nagpur and 57°F. in Orissa and has never fallen below 32°F. in the former area and 40°F. in the latter

(a) BOMBAY—JUBBULPORE—ALLAHABAD—CALCUTTA

Surface winds.—Ground winds along the Bombay—Jubbulpore section are mostly between north and east during the months October—February and between north and west in March and April, with a fairly large percentage of calms in the morning; along the Allahabad—Calcutta section the wind direction is mostly between north and west. During the other part of the year, May—September, the ground winds are mostly westerly between Bombay—Jubbulpore and between south and south-east along the Allahabad—Calcutta section, easterly winds also being quite frequent near Allahabad.

Upper winds.—(i) *October-February*—The winds near Poona, Jubbulpore and Calcutta at all levels up to 1 km are below 25 km/hr and are most frequently between north and east. At higher levels up to 3 km the strength of winds near Poona continues to be below 25 km/hr. but that near Jubbulpore and Calcutta frequently increases to 50 km/hr. In October and November, the most frequent direction near Poona is between north-east and east; in December and January, the directions are southerly up to 2 km. and between west and north-west, between 2 and 3 km. Near Jubbulpore and Calcutta the most frequent directions above 1 km. are between west and north.

(ii) *March-April*—The strength of winds near Poona in these months is below 25 km./hr. but that near Jubbulpore and Calcutta often goes up to 50 km./hr. at all heights. The most frequent direction near Poona and Jubbulpore is between north and north-east up to 1 km. and higher up it may be any direction between south and north-east. Near Calcutta, at the lower levels, it is mainly south-westerly and at higher levels it is between west and north.

(iii) *May-September*—During these months the wind generally strengthens and it often goes up to 50 km./hr. at all the places (i.e., near Poona, Jubbulpore and Calcutta). The most frequent directions during May to September, i.e., during the monsoon months, are between west and north near Poona and Jubbulpore, southerly and easterly components being quite frequent near Poona at the higher levels, generally above 2 km. Near Calcutta the direction is mostly between south and west, easterly components being also met with during storms and depressions at the head of the Bay of Bengal.

Thunderstorms and squalls.—Thunderstorms mostly occur during the period May to September along the greater part of the route, except between Gaya—Calcutta where the thunderstorm period extends from March to October. The maximum frequency of thunderstorms occurs in May and June with a

secondary maximum in September, while rainsqualls are fairly common during the months of June to September. Along the Gaya—Calcutta section, the thundersqualls of great violence known as Nor'westers occur fairly frequently during the pre-monsoon months of March to June. They generally occur in the late afternoon or early evening and occasionally attain tornadic force (the squalls reaching over 100 miles per hour, about 160 km./hr.) and cause considerable damage to life and property. They generally follow more or less straight and narrow courses from the north or north-west.

Depressions.—Depressions affect the route mostly during the period May to November, being more frequent in June to September. In May, October and November, they are the remnants of cyclonic storms originating in the central Bay of Bengal which, after a northerly travel, recurve northwards towards the Orissa coast or north-eastwards towards the Bengal coast and thus affect weather along the Gaya—Calcutta section. Some of these storms after crossing the coast travel as depressions across the Central Provinces and Central India to Gujarat and then recurve northwards to the Himalayas. These depressions affect weather along the Bombay—Allahabad route and cause heavy rain along and near their tracks. During the months of June to September the depressions develop over the head of the Bay and generally travel north-westward across the Bengal-Orissa coast. After crossing the coast they continue to travel west or north-westwards over the country and affect the weather along the route Bombay—Allahabad—Calcutta.

Cloud.—Over this route cloud amounts are greatest during the monsoon season, i.e., the months of June to September, July and August being the cloudiest months with practically overcast skies. From October onwards cloud amount begins to decrease till it is a minimum in January and February along the Bombay—Hoshangabad section; along the Jubbulpore—Allahabad—Calcutta section, the minimum occurs in November and December, cloudiness again increasing slightly in January and February in association with the eastward passage of western disturbances across northern India and then a secondary minimum occurs again in the month of April. It should be noted that over the Western Ghats between Bombay and Malegaon, in the hilly regions of the Central Provinces between Khandwa and Jubbulpore and in the Chota Nagpur plateau, the hill tops may often be enveloped in low clouds on rainy days.

Rainfall.—Bombay being situated to the west of the Western Ghats, its average annual rainfall is 71 ins. with 73 rainy days; just to the east of the Ghats the rainfall decreases to about 22 ins. annually with 35 rainy days at Malegaon. In the rugged country along the Khandwa—Jubbulpore section, the rainfall again increases until it is 55 ins. at Jubbulpore with 64 rainy days, the amount decreasing however to 39 ins. at Allahabad with 49 rainy days. Along the Gangetic plain the rainfall increases once more until it is 63 ins. at Calcutta with 85 rainy days. Most of the rainfall mentioned above occurs in the monsoon season, when during the westerly or north-westerly passage of storms and depressions from the Bay of Bengal across the country, practically continuous, and locally heavy, rain may occur in any part of the route, the individual falls of 5 to 10 ins. in 24 hrs. having been recorded. Occasionally thunderstorms may also give local heavy falls of rain, or rain and hail, along the route.

Visibility.—During the winter months, December to February, fog or mist is likely to be encountered on most mornings in the river valleys and over hilly tracks of the country. During the rainy season visibility is considerably reduced when rain is falling and is bad when the intensity of rain is moderate.

or heavy; also, over the hilly tracks, during this season visibility is reduced considerably due to low clouds persisting over the hill tops. At other times visibility is generally fair to good.

(b) BOMBAY—NAGPUR—CALCUTTA

Surface winds.—The most frequent directions of ground wind along the Bombay—Nagpur section are between north and east during October to March and between west and north-west during the rest of the year. Along the remaining portion of the route (Nagpur—Calcutta) the most frequent directions are between north and east during October to February and between south and south-west during the rest of the year.

Upper winds.—The description of upper winds for the route Bombay—Allahabad—Calcutta is generally applicable over this route as well.

Thunderstorms.—Thunderstorms mostly occur during the period March to October. The maximum frequency of thunderstorms occurs in May and June with a secondary maximum in September; they are less frequent in July and August. Rainsqualls are rather common during the months June to September. The air route through south-west Bengal is liable to the occurrence of Nor'westers during the pre-monsoon months of March to June. The character of these has already been described.

Depressions.—Depressions affect the route mostly during the period May to November, being more frequent in June to September. In May, October and November, they are the remnants of cyclonic storms originating in the central Bay of Bengal which, after a northerly travel, recurve northwards towards the Orissa coast or north eastwards towards the Bengal coast and thus affect weather along the Sambalpur—Calcutta section. Some of these storms after crossing the coast travel as depressions across the Central Provinces and Central India to Gujarat and then recurve northwards to the Himalayas. These depressions affect weather along the Bombay—Sambalpur section and cause heavy rain along and near their tracks. During the months June to September the depressions develop over the head of the Bay and generally travel north-westwards across the Bengal-Orissa coast. After crossing the coast they continue to travel west or north-westwards over the country and affect the weather along the route Bombay—Nagpur—Calcutta.

Cloud.—Along this route the cloud amount is greatest during the monsoon season, i.e., the months June to September; July and August are the cloudiest months, practically overcast skies being more frequent than in other months. From October onwards cloud amount begins to decrease till it is least in February and March along the Bombay—Nagpur section. Along the Sambalpur—Calcutta section however the minimum occurs in December, the cloud amount again increasing slightly in the subsequent months in association with the eastward passage of western disturbances across northern India. It should be noted that over the Western Ghats between Bombay and Aurangabad the hill-tops may often be enveloped in low clouds on rainy days.

Rainfall.—Bombay being situated to the west of the Western Ghats its average annual rainfall is 71 ins with 73 rainy days, but just after crossing the Ghats to the east it falls down to about 28 ins with 44 rainy days at Aurangabad. The rainfall thereafter increases gradually as one travels eastwards so that it is about 66 ins with 74 rainy days at Sambalpur. After this the average number of rainy days goes on increasing, yet the total annual

rainfall falls down and it is about 63 ins. with 85 rainy days at Calcutta. Most of the rain falls during the rainy season only. During the passage of storms and depressions from the Bay of Bengal, which are frequent between May and August and common in September and October, and during occasional thunderstorms, the route is liable to heavy falls of rain, the individual falls during 24 hrs. being between 5 to 16 inches.

Visibility.—During the winter months of December to February fog or mist is likely to be encountered on most mornings. During the rainy season visibility is considerably reduced when rain is falling and is bad when the intensity of rain is moderate or heavy. Visibility on the top of the Western Ghats is also likely to be poor to bad during the winter due to fogs and mist, and during the rainy season due to low clouds persisting over them. At other times visibility is generally fair to good.

CHAPTER 6.

KARACHI—BOMBAY—MADRAS—COLOMBO ROUTE.

Physical features.—The route passes over the lower Indus Valley, a very dry plain, over Cutch, which is a barren, rocky, treeless country, and then over Gujarat, which is on the whole a low-land region, but has numerous small hills.

It then passes over the narrow coastal plain of the west coast, across the valley of the river Tapti or the steep slopes of the Western Ghats into the Deccan plateau. The western side of this tableland is the higher, and the surface slopes down towards the east and ends in the Eastern Ghats, which are interrupted by a number of river valleys. The region which includes Berar and the western half of Hyderabad is over 300 metres above sea level, and there are large areas over 600 metres high, it is as a whole higher in the south—Mysoor—than it is in the north of the Deccan. Between the Eastern Ghats and the sea there is a broad coastal plain.

Forests cover a considerable area, and are found especially on the slopes of the Western Ghats. From Madras, the route passes southwards over the Carnatic region which falls into two parts: the lowlands near the coast, and the hilly western part. The coastal plain consists mainly of alluvium, but the hills are of old hard rocks. There are large artificial tanks or canals in this region in which rain water is stored. After passing over the great system of canals covering the Cauvery delta, and the Pamban channel, the route enters Ceylon, which consists of a central mass of mountains surrounded by broad coastal plains.

Summary of important weather features.—In lower Sind as well as in Gujarat, there are three well-defined seasons. During the cold season which extends from December to March, weather is disturbed at intervals during the passage of well-marked western disturbances and light rain falls. The disturbances are as a rule preceded by a rapid rise of temperature and succeeded by a large fall. The hot season begins in April and lasts to nearly the end of June in lower Sind and the middle of June in Gujarat. Hot dry winds prevail during the afternoon in May and June, but occasionally strong westerly winds from the coast of Sind and Kathiawar blow during the summer months, making the atmosphere less oppressive than it would otherwise be. The monsoon rain sets in in Gujarat towards the middle of June and lasts till the end of September, the rainy spells on this route during the monsoon being generally associated with depressions which advance westwards from the Bay of Bengal through the Central Provinces or the Gangetic plain. From October to December the weather is dry and temperature falls rapidly. The mean temperature in lower Sind varies between 65°F in January and 90°F in June, and averages 79°F. for the year. The maximum temperature is on an average 89°F. at Karachi and 105°F. at Hyderabad (Sind) during the hot months, the highest temperatures on record being 118° and 122°F. respectively. The lowest mean minimum of the year is 51°F. at Hyderabad (Sind) in January and no reading lower than 33°F. has yet been recorded. The annual diurnal range of temperature is 13°F. at Karachi.

In Gujarat the mean temperature for the year is 80°F., that of January 69°F. and that of May 89°F. The average maximum temperature of the year is 91°F. and the minimum 69°F., from March to June maxima exceeding 107°F. are occasionally registered in places away from the coast, and rise as high as 120°F. in May and June. At night nowhere does the thermometer sink to the

freezing point, and except at Deesa, Bhuj, Ahmadabad and Rajket it has never fallen below 40°F.

Over the portion of the route which lies over the west coast, the climate is exceedingly damp and uniform. In May the weather is cloudy and occasional showers and lightning coming from some south-easterly direction may be expected. Occasionally, a gale from the south-west may occur. At evening in May and early June, heavy clouds sometimes collect and squalls may occur with rain at night. The wet season lasts from June to October and the annual rainfall is 71 ins. in Bombay while over the Ghats rainfall varies from 200 to 350 inches. The mean temperature for the year is 79° or 80°F.; the warmest month is May and the coolest January.

The route then passes through the interior of the Peninsula and this is a zone which is much drier than the west coast. Its annual rainfall is less than 40 inches; in a strip parallel with the Ghats down to Mysore it is still less, between 20 and 25 inches. In the north rainfall occurs chiefly between June and October, but in the south the rainiest season is from October to December. The months of maximum thunderstorm activity are October, November and May.

The vicissitudes of temperature in the route from Bombay to Madras are much smaller than in the extra-tropical regions and the large and sudden variations which characterize northern India during the winter months are seldom met with. As a rule the coolest month is December and the warmest May (except on the tableland of Mysore, where it is April), but the amplitude of the change is everywhere less than 20°F., or barely half of that in the Punjab.

The mean maximum of the year varies between 83° and 96°F. and the minimum between 63° and 77°F. Hot land winds prevail in the spring, and very high temperatures, occasionally ranging up to 105°F. and beyond, are recorded, except on the plateau of Mysore. The air is exceedingly dry even the greater part of the Bombay Deccan in March and April, particularly in the afternoon, when humidities below 20 per cent. are recorded.

The route from Madras to Colombo lies near the east coast of the Peninsula. This region is dry as compared with the west coast. The average annual rainfall, however, exceeds 40 inches. Rainfall chiefly occurs from October to the middle of December, when the monsoon current is backing down the Bay. November is the rainiest month and also the month when this area is most liable to be affected by a series of cyclonic storms, travelling west or north-westwards from the south of the Bay of Bengal and causing spolls of strong winds and severe rain-squalls. The weather improves in December and is generally fine in January and February with much clearer skies and very little rain. Weather is generally fine during March to May, interrupted occasionally by thunderstorms. Depressions sometimes form in the centre or south of the Bay and during the first half of May may move in some westerly direction towards the Madras coast, and, for a time, establish weather similar to that of November. During the south-west monsoon this part of the route is comparatively unaffected, except the portion near Colombo, where the full fury of winds and rain is experienced during the onset of the monsoon. Sometimes very heavy and sudden showers of 2 to 4 inches are received in September. The atmosphere often remains hazy in September. October has more unsettled weather and at times there are heavy squalls with rain towards the end of the month. About the middle of November, the north-east monsoon is ushered in by lightning, thunder and heavy rain.

The mean temperature of the year is 81°F.; the hottest month is May with a mean temperature of 88°F., and the coolest January, 74°F. Unlike the west coast the tract from Cochin southwards is exposed to the hot winds from the interior, and very high temperatures (between 108° to 118°F.) are occasionally recorded during the period from April to June.

Surface winds.—The surface winds over the route during the monsoon and the winter months are largely controlled by the south-west monsoon current and the north-east monsoon current respectively. In the transition months, April and May, when the north-east monsoon current is changing to south-west, as well as October and November, when the south-west monsoon current is changing to north-east, the winds are variable over most parts of the route.

(a) *Karachi to Ahmadabad*—Weather is generally fine over this route in the cold weather months. Local gales and squalls may, however, occur occasionally during the passage of western depressions from Persia to north-west India. During December and January moderate morning land-breezes alternate with afternoon sea-breezes along the Sind and Kathiawar coasts, the land breeze is the predominating feature and at times blows continuously for two days or more on end. From February onwards the westerly and south westerly sea-breezes become gradually more pronounced and from April onwards they blow by night as well as by day, being strongest in the afternoons. The south-west monsoon sets in in June, attended with overcast skies, occasional showers and strong winds at times rising to a fresh gale. It remains vigorous throughout July and August and weakens rapidly in September.

(b) *Ahmadabad to Bombay*—During the cold weather the wind blows, on the average from some northerly direction, in October from north-west, in November, December and January from north and in February from north-north-east. Near the coast the daily land and sea breezes are well marked, blowing from the north-east in the mornings and from the north-west in the afternoons and evenings. From March to May the average wind direction backs from north-west to west-north-west and the land breezes become very uncertain, seldom coming off till morning. A feeble land breeze sometimes develops, but more frequently light air from north and calms may be expected from nearly mid-night to about noon on the following day when the north-west sea wind again sets in. Sometimes these north-west winds are particularly strong.

North-westerly winds continue, but are often variable and uncertain in May. The south-west monsoon normally sets in after the first week of June, and up to the middle of August weather is generally very unsettled with hard squalls, much rain and dark cloudy weather. The monsoon begins to weaken in August and begins to retreat towards the end of September. A period of light variable winds and frequent calms and cloudy weather and occasional showers intervenes. After this period the northerly winds of the winter months are established.

(c) *Poona to Madras*—In the winter months, December to February, the surface wind over this portion of the route is usually from some easterly direction, the strength varying from 5 to 30 km./hr. In the months of March and April the wind becomes variable. In May the surface wind becomes, more or less, steady and generally blows from a west-north-westerly direction, the speed being 5 to 15 km./hr. The monsoon sets in in the early part of June and rapidly extends into the Deccan, when the wind becomes more westerly, the average speed being 15 to 30 km./hr. The monsoon generally remains

active until the end of August, with occasional breaks, when the wind current suffers a decrease in speed. In September, with the gradual weakening of the monsoon current, the wind over this part of the route becomes west-north-westerly. In October the wind again becomes variable in direction. In November the wind becomes easterly with an average speed of 5 to 15 km./hr. and leads to the establishment of the north-east monsoon. In December, which is a typical north-easterly monsoon month, the wind over this route blows from some south-easterly direction with an average speed of 5 to 15 km./hr.

(d) *Madras to Colombo*.—Weather is generally calm during the first part of October over this route but, later, winds from some direction between north and east set in and prevail until about the middle of February. Land and sea breezes remain very weak throughout this period, being at their minimum in November. The winds are less steady or strong in February, when the normal direction at Madras is easterly. Thereafter, land and sea breezes strengthen; they increase rapidly in March and April and are most strongly in evidence during the period May to September except on those days during which the south-west monsoon is strong. The land wind blows in the morning hours after sunrise, and after a lull, at about noon, the sea breeze commences in the early afternoon. In March and April south-easterly winds predominate and become very strong during the day. They veer towards the south as the season advances, sometimes blowing directly or nearly directly from the south. The average wind direction in Madras in May is south-westerly, but it undergoes greater variations in direction and strength during the 24 hrs. each day in this month than at any period of the year. Occasionally indeed, a westerly wind prevails in this month throughout the day so that the sea breeze, which usually sets in about the mid-day, does not appear at all. In June south-westerly winds prevail, but only occasional showers and rain-squalls occur in this month. During July, August and September the south-westerly wind becomes slightly weaker and rain-squalls become more and more frequent and showers increase on the Madras coast. Calms are frequent towards the end of September.

In the Gulf of Mannar winds become light and variable and squalls and showers of rain occur at night towards the end of April. The sky becomes overcast occasionally in May, banks of clouds rising over the ocean; and winds begin to blow continuously from the south-west. The south-west monsoon gains strength in June, but showers become less frequent in July and weather is cloudy and hazy with generally a fresh breeze; the wind moderates near the head of the gulf in the morning and blows strong again in the afternoon. Fresh south-westerly to west-south-westerly winds continue in August and September, but the weather is generally fine; in the afternoon the breezes are strengthened and are accompanied with occasional squall and rain. During November the winds are light and variable between north-east and west-north-west. The north-east monsoon lasts till the end of January and blows steadily from north-north-east along the south Madras coast, but in the north-west part of Ceylon it is modified into land and sea breezes.

Upper winds.—(a) *Karachi to Ahmadabad*.—In the months December and January, the upper winds in the first kilometre over the route Karachi—Ahmadabad are from a north-easterly to north-westerly direction and have an average speed of 15 km./hr. The wind backs with height and at 2 and 3 km. it blows from some westerly direction. In February and March, the usual directions in the first kilometre lie between west-north-west and north-east and become more and more definitely westerly with increase of height up

to 3 km. The average speed irrespective of direction is 15-25 km/hr. In April and May, the winds are mainly westerly to north-westerly in the first half of the route, but in the second half south-westerlies are more frequent than north-westerlies at 2 and 3 km. The average speeds lie between 20 and 35 km/hr. With the advance of the monsoon in June, the wind over lower Sind in the first kilometre comes more or less steadily from a westerly direction, it flows from between west and north at 2 km and from between north and north-east at 3 km. Near Ahmadabad the winds are westerly to south-westerly up to 2 km and indefinite in direction at 3 km. The average speeds at 0.5 and 1 km during the monsoon months are 25 to 35 km/hr. While the monsoon is retreating southward in October, the frequency of westerly winds decreases, giving place to northerly and north-easterly winds. The mean speed also decreases to 15-20 km/hr.

(b) *Ahmadabad to Hyderabad*—In December to March, the upper winds are variable in direction with north-westerly to north-easterly winds predominating and are light to moderately strong. In April, the winds in the first half of the route come in the first kilometre from a north-westerly direction and gradually back to west-south-westerly at 3 km. In the second half, they are variable in the first 2 km and become north-easterly at 3 km. In May, the winds over the whole route become westerly to north-westerly in the first kilometre the mean speed increasing to 20-35 km/hr, and, although at higher levels for half the route from Ahmadabad the direction remains westerly, in the latter part of the route it becomes northerly to north-easterly at 3 km. During the monsoon months June to August, the upper winds at all levels over most of the route are generally westerly or south-westerly, although near Ahmadabad the wind direction above 2 km is variable. The mean wind speed at 1-2 km increases from about 30 km/hr near Ahmadabad to about 45 km/hr near Hyderabad. Velocities may go up to 75 km/hr. during periods of activity of the monsoon. In September and October the winds are variable both in direction and velocity. In November also they are variable and weak in the first half of the route from Ahmadabad but easterly to north-easterly winds blow in the latter half with mean speeds of 15-25 km/hr.

(c) *Hyderabad to Madras and Colombo*—In December, January and February, the most frequent direction of wind at all heights up to 3 km is northerly to easterly. There is greater variability at upper levels than near the surface. Wind is either light or moderate, the velocity seldom exceeding 50 km/hr. In March, the wind is very variable at 0.5 and 1 km level, with a predominance of south-easterly winds near the east coast, it becomes easterly or north-easterly at 2 km and 3 km levels. On certain occasions there is an increase of speed with height, reaching a speed of 25-50 km/hr. at 3 km level. In April, the most frequent direction at 0.5 and 1 km level is southerly but the direction is variable at 2 km. At 3 km level, the direction is on a large percentage of occasions north-easterly. The velocity of wind is either light (6-25 km/hr) or moderate (26-50 km/hr.). In May, the wind is variable at all levels up to 3 km, usually it comes from some direction between south and west at 0.5 and 1 km, and veers to some northerly direction at 2 and 3 km. The speed, however, remains light or moderate. During the monsoon months, June to September, the wind comes from some westerly direction at all levels up to 3 km, it becomes somewhat variable towards the end of this season. The speed may be light, moderate or strong according to the strength of the monsoon, but in September there is a decrease in the speed and it is either light or moderate. In October, the wind is variable at all heights, and is either light or moderate, unless there is a depression or storm in the Bay of Bengal.

In November, the most frequent direction is north-easterly at 0.5 and 1 km. level; but at 2 and 3 km. levels it is variable and may come from any direction between north and east. The velocity is either moderate or light unless there is a storm in the Bay of Bengal.

Storms.—Storms may occur, though not frequently, in the Arabian Sea during the latter half of April. They are generally severe and their usual course is north-north-westwards and, when they move across the head of the Arabian Sea, recurving to north-west or north-east, they may cause very strong winds and squally weather and heavy rain over the route Karachi to Poona. In the month of May there is an increase in the number of storms, which form in the Arabian Sea. Those storms which travel fairly close to the coast in some north-north-easterly direction and recurve subsequently to some north-westerly direction seriously affect the weather conditions over the route Karachi to Poona. In the Bay of Bengal, all the storms of the month of April usually travel towards the Burma coast and do not affect the route Madras to Colombo, but in the month of May storms forming in the south or the centre of the Bay may travel in some north-westerly direction and cause severe weather over the route Bellary to Madras and Madras to Colombo. The monsoon storms forming over the head of the Bay of Bengal and travelling over the Central Provinces or the Gangetic plain to north-west India, may produce highly disturbed weather over the route Karachi to Bombay. The post-monsoon storms, forming in the Bay of Bengal or the Arabian Sea, are generally of severe intensity. Those which form in the eastern side of the Arabian Sea usually travel at first in a north-north-westerly direction and then recurve to north-east and produce when nearing the coast highly disturbed weather over the route Karachi to Poona. In the Bay of Bengal storms may form in any part of October and move in any direction between west and north with a tendency to recurving to north-east. Those which strike the Coromandel or the Circars coasts may produce rough weather over the route Bellary to Madras. In the month of November, on the other hand, storms generally form in the south Bay of Bengal and a fair percentage of them move in a westerly or north-westerly direction and strike the Madras coast. Some of them cross the Peninsula, slightly weakening in intensity, and develop again in the Arabian Sea and travel north-westwards, later recurving to north-east towards the Konkan and Kathiawar coast. These storms, therefore, cause rough weather at first over the route Bellary to Colombo and at later dates over the routes Poona to Bellary and Karachi to Poona.

Cloud.—The cloudiness is maximum over the whole route Karachi to Madras during the monsoon months June to September, when it varies from amount 6 to overcast skies. During the winter months, December to March, the clouds over the route Karachi to Bellary are generally associated with western depressions. When there are no depressions moving across northern India, the sky generally remains clear. Over the route Bellary to Madras and Madras to Colombo, the cloud amounts during this period are controlled by the activity of the north-east monsoon. During periods of strong north-easterly monsoon, skies are generally overcast; skies remain clear or partially clouded only when the north-east current weakens. In the months, April and May as well as October and November, cloudiness over the route is controlled largely by the thunderstorms associated with the advancing monsoon or the oscillations of the current associated with the retreating monsoon. The sky over the route Karachi to Madras remains almost always clear or partially clouded during these periods.

Rainfall.—See General summary, p. 44.

Visibility.—The horizontal visibility at the surface is usually good on the route Karachi to Poona, except on a small percentage of occasions in the months of November and December and March, April and May due to fogs or dust-haze. In the monsoon months, surface visibility is always good, except over the hills which may very often be covered by low clouds. Over the route Poona to Madras, the visibility usually becomes bad on a small percentage of occasions in the months of March, April and May as well as November and December due to fog or dust-haze. Over the route Madras to Colombo, the visibility is always good, but on rare occasions in the months of March and November, visibility may be rendered poor on account of fog. In the neighbourhood of the Gulf of Mannar, the atmosphere often remains hazy in September.

CHAPTER 7.

CALCUTTA—MADRAS ROUTE.

Physical features.—Passing over deltaic Bengal, the route enters the Orissa coastal strip and the Circars region, which although a coastal region is scarcely a coastal plain, for there are many small hills, some of which come right to the sea. The region lies between the crest of the Eastern Ghats and the Bay of Bengal. The central part is made up of the big deltas of the Godavari and Kistna rivers. These deltas are irrigated. The flat areas are of alluvium, but the hills are of crystalline rocks. On the damper hills there are forests. The route finally passes over the northern Carnatic region to Madras.

Summary of important weather features.—In the north rainfall occurs chiefly between June and October and in the south from October to the middle of December, when the monsoon current is backing down the Bay. The average annual rainfall exceeds 40 ins., except in the portion from Cocanada to Nellore, where it varies between 30 and 40 inches. The mean temperature of the year is 82°F.; the hottest month is May with a mean temperature of 87°F., and the coolest January, 73°F. Unlike the west coast the tract from Cocanada southwards is exposed to the hot wind from the interior, and very high temperatures (between 108° and 118°F.) are occasionally recorded during the period from April to June.

The cold season lasts from December to February; and during this period the northern part receives light rain from winter depressions. Thereafter sea winds begin to blow from the head of the Bay and during April and May give rise in this part to frequent thunderstorms, hailstorms and Nor'westers.

The mean humidity of the year exceeds 70 per cent. in the coast districts. Bengal, while exposed to the moist winds during at least three-fourths of the year, is almost out of the reach of hot winds which blow down the Gangetic plain in April and May. Its climate is accordingly very damp and relaxing. Calcutta has an average rainfall of 63 ins. and Cuttack of 59 inches. The mean annual temperature is about 79°F. in south Bengal and about 82°F. in the neighbourhood of Cuttack. The average afternoon temperature of the hottest months, April and May, is 90°F. and upwards; the highest temperatures yet recorded in Bengal are 117°F. in Midnapore and Bankura and 115°F. at Berhampore. The afternoon temperatures in Orissa are somewhat mitigated by the moist easterly winds that are felt intermittently, and vary between 88° and 106°F.

Surface winds.—(a) *Calcutta—Puri—Vizagapatam.*—In the middle of October the south-west monsoon winds are replaced by light unsteady northerly winds. As the season advances, these northerly winds increase in steadiness and velocity; and in November and December blow as dry land winds from north-north-west to north-west in the mornings and veer to north-north-easterly to north-easterly directions in the afternoon. Dry northerly land winds and fine weather prevail as a rule in January and the greater part of February except during the passage of western depressions across north-east India. During these disturbances winds usually shift round to southerly directions. There is a feeble in-draught of local sea breezes across the Bengal coast by early March. These southerly winds gradually strengthen, are vigorous and steady in April and May and continue unchanged in general character until the first or second week of June, being sometimes of exceptional strength.

These winds advance chiefly into Bengal and Assam and give rise to frequent afternoon and evening thunderstorms or Nor'westers

Throughout the south-west monsoon period the predominating winds are south-westerly on the Orissa coast and southerly to south easterly on the Bengal coast. The change from the local southerly winds to the winds of the south-west monsoon proper usually occurs in the second or third week of June and is generally ushered in by the advance of a cyclonic storm of moderate intensity with the monsoon enroute in its rear. From the commencement of the south-west monsoon in June to the end of September or middle of October, a series of cyclonic storms or depressions form in succession at the head of the Bay. The weather in this period consequently alternates between periods of stormy conditions with showers and rain squalls during the movement of these storms westwards and periods of light unsteady winds after they have passed inland. The south-west monsoon usually withdraws in the first half of October.

(b) *Vizagapatam—Madras*—The dry season sets in by the end of November and lasts till early May over the portion of the route between Vizagapatam and Nellore, but the establishment of the north-east monsoon continues to give rain over the portion Nellore to Madras in December. The mean winds are generally north-easterly during November and December, veer round to east during January, and become east south east to south-south easterly in February and the first half of March. Land and sea breezes are well marked during the cold weather months, December to February. There is a pronounced shift in the predominating winds by the end of March when they become southerly to south-westerly, the weather remaining fine throughout. This condition persists till the end of May. In June, south-westerly winds prevail with occasional showers and rain squalls. During July to September, the south-westerly winds become weaker and rain squalls become more and more frequent and showers increase on the Madras coast. Over the Ganjam coast, steady south-westerly winds predominate from July to the end of August. During the withdrawal of the south-west monsoon, in September, October and November, this coast gets rain and squally weather under the influence of cyclonic storms which generally form in the central Bay of Bengal and move towards the coast. In October the winds shift to a northerly direction and gradually the north-easterly winds of the cold season set in. By the end of October or early November the rain slackens and feeble land and sea breezes are gradually established.

Upper winds.—With the establishment of the north-east monsoon by the middle of November, the upper winds in the first kilometre become northerly near Calcutta and north-easterly between Vizagapatam and Madras. The average wind speed at 1 km gradually increases from about 15 km/hr near Calcutta to about 25 km/hr near Madras. When storms from the Bay of Bengal are approaching the Madras coast, northerly winds may increase in speed to 100 km/hr. At higher levels, the winds over Calcutta and Orissa back to north-west and west and also increase in strength. Between Vizagapatam and Madras, the winds continue to be from some north-easterly direction. They are steadier and stronger near Madras than near Waltair. The wind system does not undergo much change in December and January, except that the north-westerly to westerly winds at 2 and 3 km over Bengal become stronger. In February although the most frequent direction over lower Bengal and Orissa in the first kilometre continues to be from the north-west, south-westerly winds become more and more common over the section Calcutta to

Vizagapatam. In March and April, these south-westerlies become still more frequent and the wind direction between Vizagapatam and Madras becomes easterly to south-easterly. The mean wind speed in this layer varies from 15 to 35 km./hr. In May, between Calcutta and Vizagapatam, the winds up to 1 km. are mainly south-westerly, while at 2 and 3 km. they are from west to north-west. In the portion Vizagapatam to Madras, the wind direction in the first kilometre is generally from the west and at higher levels from north-east to north-west. The directions are variable at about 2 km. especially in the middle third of the route. The average speed is 15-35 km./hr. With the onset of the monsoon in June, the wind direction up to 1 km. along the whole route becomes westerly to south-westerly, but at higher levels westerly to north-westerly winds prevail. The average wind speeds are 25-40 km./hr., the greater speeds occurring between Vizagapatam and Madras. In July and August, the wind direction ranges from south to west near Calcutta and from west to north-west near Vizagapatam; near Madras it is mainly westerly. In September, with the weakening of the monsoon current, the wind again becomes variable but generally blows from some south-westerly or north-westerly direction at all levels up to 3 km. in the portion of the route between Vizagapatam and Madras. The wind up to 3 km. is more variable in the portion of the route between Calcutta and Vizagapatam; it may come from a northerly or a southerly point. There is a decrease in the average wind speed in this month; it is generally light or moderate at all heights up to 3 km. The wind continues to remain variable up to 3 km. in October, but in November it tends to become north-easterly or easterly at all heights up to 3 km. in the southern half of the route. The speed is either light or moderate except when it is influenced by a storm in the Bay of Bengal.

Storms.—A large percentage of the pre-monsoon and post-monsoon storms and cyclones which form in the middle or the lower part of the Bay of Bengal follow a track which is more or less parallel to the Circars and Orissa coasts and sometimes not far away from these coasts, or they actually strike these coasts. They, therefore, cause for several days at a time stormy weather over this route, and when they are very near the coasts or crossing the coasts, cause winds of gale or hurricane force, according to the intensity of the storm, and torrential rain.

The storms and depressions which form over the head of the Bay of Bengal in succession during the south-west monsoon cause highly disturbed weather over the route Calcutta to Vizagapatam.

Cloud.—The maximum cloudiness occurs in the monsoon months, June to September, the mean cloud amount being on the average about 8. The mean cloud amount, however, decreases to about 4 or 5 in the month of October. In the months November and December the sky is usually more cloudy over the south Circars and Coromandel coasts than over the north Circars and Orissa-Bengal coasts where the mean amounts vary from 2 to 4. During the winter months, December to March, the cloud amount over the Orissa-Bengal coast and north Circars coast is usually between 1 and 3, the cloud being mostly caused by the passage of western depressions across northern India. Over the south Circars and Coromandel coasts, the cloud amounts are, however, somewhat higher in the months of November and December, being on the average between 4 and 5 as a consequence of the north-east monsoon. The amount decreases with the advance of the season and is between 2 and 4 in the months of January to April. There is a slight increase in the cloud amount with the approach of the monsoon in the month of May.

Rainfall.—*See* general summary, p 50.

Visibility.—Visibility is generally good over this route except during heavy rain in association with storms or cyclones in the Bay of Bengal during the pre monsoon and post-monsoon months. For the same reason visibility may be rendered poor during strong south-west monsoon over the northern part of the route and during strong north-east monsoon over the southern part. Over the Eastern Ghats, visibility may become bad on account of the hill-tops being covered by low clouds during the pre monsoon, post monsoon and monsoon periods. From the middle of December to the end of March, visibility is generally good over this route, except for local early morning fogs. Dust storms or dust haze rarely occur over this route.